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The Eighteenth Annual Meeting of the American Association for Thoracic Surgery, New York City, June 3, 4, and 5, 1935

Vol. 4 JUNE, 1935 No. 5

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The American Association for Thoracic Surgery

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Published Bi-Monthly by
The C. V. Mosby Company, 3523 Pine Blvd., St. Louis, U. S. A.
Entered as Second Class Matter at Post Office at St. Louis, Mo.

The Journal of Thoracic Surgery

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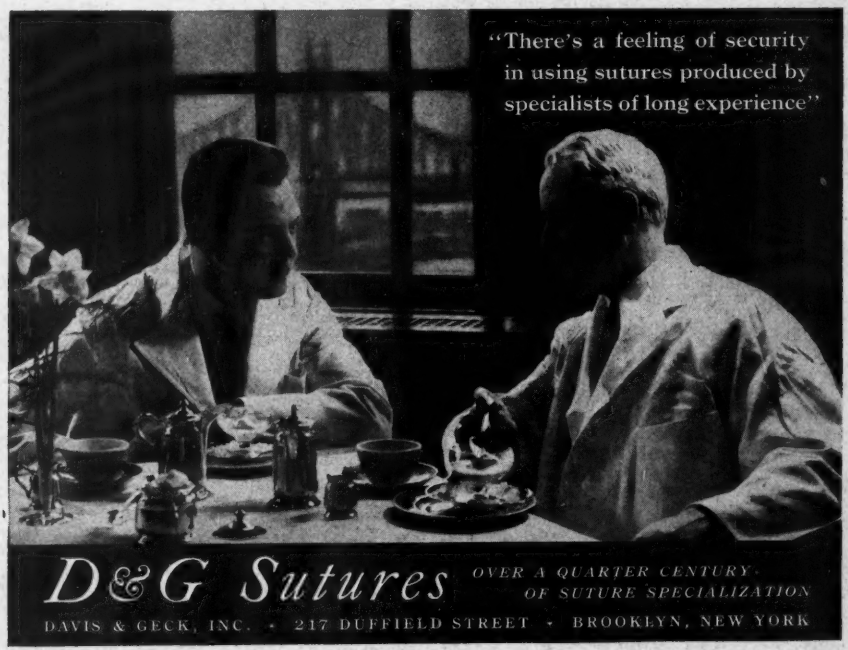
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The Journal of Thoracic Surgery

VOL. 4 JUNE, 1935 NO. 5

Original Communications

PRIMARY MALIGNANT TUMORS OF THE THYMUS GLAND*

WITH REPORT OF TWO CASES

H. RYERSON DECKER, M.D., PITTSBURGH, PA.

IN CLINICAL practice abnormalities of the thymus gland are largely the benign hyperplasia of infancy, and more rarely the hyperplasia associated with Hodgkin's disease, exophthalmic goiter, myasthenia gravis, leucemia, and status lymphaticus. Malignant growths, while comparatively rare, are being reported frequently enough to emphasize their importance as a clinical entity, and the need of keeping a close lookout for them.

In a report of 17,000 autopsies at Bellevue Hospital, Symmers[1] found twenty-five malignant thymic tumors, i.e., 0.14 per cent. At the University of Pittsburgh, two cases were observed in 3,725 autopsies, or 0.05 per cent. E. H. Crosby[2] in 1932 published a review of all malignant tumors of the thymus reported to that time; 166 in number classified by him as sarcoma 122 and carcinoma 44. Since then there have been additional reports of 40 cases. The two cases herewith discussed make a total to June, 1934, of 208.

Pathology.—Malignant tumors of the thymus have decided interest for the pathologist and the clinician alike, because they are difficult to diagnose not only in the early stage but even during the lifetime of the individual, and because they baffle successful treatment; for the pathologist, because of the uncertainty and the difficulty of classification.

That there should be disagreement among pathologists is not surprising, since the origins of the thymic cells are still undetermined. The gland develops bilaterally from the entodermal epithelium of the third branchial cleft. In the second month of fetal life the lobular epithelial

*Read by title before the Seventeenth Annual Meeting of the American Association for Thoracic Surgery at Boston, May 31, June 1, 2, 1934.

reticulum becomes infiltrated with migrating lymphocytes of mesenchymal origin, and these in turn may differentiate into granular lymph cells or into plasma cells. Are these the true thymic cells, or are thymic cells derived from the entodermal reticulum as Ewing and the monist school believe? There is general agreement that Hassall's corpuscles, appearing as concentrically laminated rests of flattened epithelial cells, are of entodermal origin.

The simplest classification of these tumors is that of Ewing,[3] who describes lymphosarcoma, carcinoma, sarcoma, and endothelioma.

Lymphosarcoma is a tumor in which the normal cortical and medullary structure of the gland is replaced by a diffuse growth of small round lymphocytes, densely packed into an inconspicuous connective tissue stroma, with a liberal supply of small vascular channels. One variety is hard to distinguish from the granuloma of Hodgkin's disease, and in this connection one must recall the highly sarcomatous appearance of Hodgkin's disease arising in, or in the region of, the thymus. Such cases are often called Hodgkin's sarcoma.

Carcinoma presents pavement or cuboidal or cylindrical epithelium arranged in cords and columns of large flat polyhedral cells, with or without Hassall's corpuscles. Lymphocytes are comparatively small in number.

Sarcoma is a tumor of the connective tissue stroma. *Endothelioma* is a tumor arising from the blood vessels. Lately, however, Ewing has said that there is strong ground for believing that sarcoma and endothelioma are of parenchymal rather than of connective tissue origin.

Matras and Priesel[4] classify parenchymatous thymic tumors as (1) purely epithelial (benign and malignant epithelioma); (2) lymphoepithelial (with compact epithelial structures and loosely scattered lymphocytes, which are compact perivascularly); (3) lymphoreticular (tumors with preponderating lymphoid cells among marked reticular loosening of the epithelial portion). They stress that a tumor can be classified under the two last varieties only after exhaustive examination of many sections, showing preponderance of lymphoepithelial or lymphorecticular characteristics.

Periepithelioma is described by Symmers as a tumor in which there are collections of spindle cells arranged in units radiating from the walls of the blood vessels; though the radiate formation soon gives way to islands and columns of variable size and shape.

Teratoma is a rare finding and is not considered proved by some pathologists.

Thymoma.—Because the histologic picture is confused by the presence of many types of cells, lymphoid, giant eosinophiles, plasma, epithelial, and by the polymorphism of these cells, many writers have used the term thymoma, introduced by Grandhomme[5] in 1900, to include all malignant

tumors of the thymus, whether carcinoma or sarcoma. Much confusion has arisen, however, because of the various designations of the term. Thus by thymoma, Brown[6] means carcinoma; Crotti[7] all tumors; Bell[8] nonmalignant tumors; Margolis[9] all tumors of parenchymal origin. Symmers insists that the term thymoma, which literally means tumor of the thymus gland, should be used only when the tumor faithfully reproduces the structure of the thymus as a whole, including lymphocytes, Hassall's corpuscles, and the epithelial reticular cells. Otherwise he says it is a "physiological desecration." Since scarcely any tumor reported reproduces all the cell structures of the thymus, I believe the term thymoma should be dropped, and Ewing's classification hold sway. If used, it should designate and include all malignant growths of the gland.

There is one practical reason why carcinoma and sarcoma should be distinguished from one another. Sarcoma is radiosensitive, and carcinoma is not; therefore, other things being equal, sarcoma offers a more favorable prognosis and opportunity for therapy.

No matter what may be their histologic differences in structure, all malignant tumors of the thymus have a similarity in gross appearance. A review of the findings in 60 autopsy cases shows that the usual tumor is located in the superior and anterior mediastinum, and tends to be encapsulated in the mediastinum; folds around in crablike fashion and compresses, rather than invades the intrathoracic contents, trachea, bronchi, pericardium, heart, pleura, and lung. In color it is pearly gray or creamy; though lemon, milky brown, and salmon are described. In consistency the growth is firm or hard, and even cartilaginous, depending upon the degree of fibrosis. At times, however, it is soft and vascular. Softening from necrosis and suppuration is occasional. Cystic formation is rare. In size the range is from 6 cm. × 4 cm. × 2 cm. to 30 cm. × 12 cm. × 3.2 cm. Hassall's corpuscles are recorded in 38 per cent of the growths.

As the tumor grows, it may break through its pseudoencapsulation and involve the adjacent viscera by direct extension, rather than by metastasis. Lymph glands, bronchial, cervical and axillary, become involved. The chest wall is invaded late. Metastases to the extrathoracic viscera are late. Foot[17] speaks of a definite tendency not to metastasize below the diaphragm. Symmers' observation led him to describe in the growth behavior of the tumors an early tendency to set up an array of destructive changes seldom paralleled in the domain of disease. He has established the following postulates for the diagnosis of thymus tumors.

1. Position in superior and anterior mediastinum.
2. Solidity.
3. Histology in keeping with histologic structure of the thymus.
4. Absence of any other growths that would be called primary.

5. Scheme of invasion and destruction of tissue.
6. Shape to suggest many-fingered contour of the thymus.
7. No more logical cause to be determined in the anterior mediastinum than the thymus.

Crosby's study of metastasis of 144 cases is classified and arranged in Table I. The infrequent involvement of the trachea and the thyroid gland and an occasional involvement of the central nervous system by carcinoma and of the spleen by sarcoma are of interest.

TABLE I

ORGANS INVOLVED BY METASTASIS IN MALIGNANCY OF THE THYMUS
(BY E. H. CROSBY)

		SARCOMA	CARCINOMA
Lymph nodes	thorax	47.2%	40.6%
	neck	25.0%	9.3%
	abdomen	22.0%	3.1%
Lungs	right	41.8%	53.1%
	left	41.8%	56.2%
Pleura	right	36.4%	40.6%
	left	36.4%	44.6%
Pericardium		37.8%	31.3%
Myocardium		12.1%	9.3%
Trachea		5.4%	9.3%
Abdominal Viscera			
Kidney	right	20.2%	6.2%
	left	22.9%	6.2%
Liver		20.2%	31.3%
Spleen		14.8%	
Pancreas		5.4%	3.1%
Suprarenal	right	1.3%	3.1%
	left	1.3%	3.1%
Ovary		1.3%	3.1%
Stomach		1.3%	
Intestines		1.3%	
Peritoneum		1.3%	
Central Nervous System			
Brain		0.0%	6.2%
Dura		0.0%	1.3%
Spinal cord		0.0%	1.3%
Blood Vessels			
Intrathoracic		1.6%	15.6%
Extrathoracic		2.6%	3.1%
Muscles			
Chest wall		1.3%	6.2%
Diaphragm		11.1%	3.1%
Intercostal		4.0%	
Bone			
Sternum		9.4%	3.1%
Clavicle		2.7%	
Rib		4.0%	
Humerus		1.3%	
Scapula		1.3%	
Vertebra		2.7%	15.6%
Femur		10.0%	1.3%
Thyroid		4.0%	3.1%
Skin		1.3%	3.1%

In passing, a comment should be made upon the relationship of thymic tumors to myasthenia gravis. Symmers found growths in 20 per cent of cases of myasthenia gravis at autopsy, including simple hyperplasia, sarcoma, periepithelioma, and epithelioma. Bell states that there are abnormalities of the thymus in nearly 50 per cent of cases of myasthenia. Most commentators, however, feel that thymic enlargements in this disease are not true tumors, but a special form of hyperplasia. Three cases of myasthenia were treated by thymectomy with good results. In view of this, it would seem that there is some relationship that is not merely coincidental; however, the causal factor is far from being established.

The recognition of thymus malignancy in the early stages of the growth is difficult because there are no unusual or characteristic symptoms. The onset is insidious, either without previous illness or at times following an infection of the respiratory tract. There are persistent cough without sputum and a variable degree of dyspnea. Then symptoms indicative of mediastinal pressure appear either gradually or in early and insistent form, such as pain, hoarseness, cyanosis, and dysphagia. A tumor may develop in the anterior chest wall or cervical region. Lymph glands in the cervical region and occasionally in the axillary, become enlarged and pleural effusion and engorgement of the superficial veins of the neck, chest and shoulders, and edema of the extremities follow. Later in the course there are fever, loss of weight, and anorexia.

Physical Signs.—On examination of the chest by percussion an area of enlarged dullness is usually mapped out extending behind and to the side of the sternum. If there is pressure on the lungs, breathing may be bronchovesicular, or bronchial in quality. If pleural effusion has developed, the breath sounds are diminished in intensity, and quality is altered in proportion to the compression exerted by the fluid.

A second group of cases, even more silent than the first, presents few if any signs of intrathoracic pressure. A physician is consulted only because of the appearance of a tumor of the chest wall, or neck, or a glandular swelling in the neck, or because of symptoms arising from a distant metastasis. Thus in several cases, for example that of Symmers and Vance, pain in the back and focal signs pointed to an extradural spinal tumor, which was removed by operation. At autopsy three months later the primary lesion was found to be that of the thymus gland.

In a third group a concomitant disease or syndrome overshadows the thymic picture, e.g., myasthenia gravis, lymphatic leucemia, exophthalmic goiter, pulmonary tuberculosis, or, as in one of our own cases, pulmonary suppuration. Then the malignant tumor is found only at autopsy.

X-ray examination is extremely helpful and important in view of the paucity of early subjective symptoms, since the appearance of a thymic

tumor shadow is fairly characteristic. High up in the mediastinum capping the cardiac shadow there is a more or less circular, flattened, sharply defined, nonpulsating mass that does not invade the other organs. Other types of tumors are even at a higher level, or lie in the middle or the posterior planes of the mediastinum. Mediastinitis throws an irregular shadow pointing to adhesions and glandular involvement. At times an intrathoracic mass due to Hodgkin's disease is extremely difficult to differentiate, as is also aneurysm; because of the proximity of the great vessels a thymic tumor in fluoroscopy may seem to have expansile pulsation.

Blood Examination.—There is nothing in the blood picture that is characteristic. There may or may not be a secondary anemia. Usually there is a low grade leucocytosis with a relative increase in the polymorphonuclear cells, and this is probably the result of a concomitant infection of the lung, pleura, or lymphatic glands.

An analysis of the symptoms reported in one hundred cases is shown in Table II. As between carcinoma and sarcoma no striking difference in subjective and objective findings can be recorded, except that a visible or palpable tumor was present four times as frequently in sarcoma.

TABLE II

ANALYSIS OF SYMPTOMATOLOGY IN ONE HUNDRED CASES

SUBJECTIVE		OBJECTIVE	
Dyspnea	66%	Physical signs of tumor in chest	55%
Cough	48%	Signs of superficial venous stasis	44%
Pain	34%	Enlarged lymph nodes. Tumor by x-ray	30%
Dysphagia	27%	Cyanosis	29%
Hoarseness	12%	Sputum	23%
Vomiting	6%	Loss of weight	18%
Sore throat	4%	External tumor	17%
Choking	3%	Pleural effusion	17%
Anorexia	1%	Fever	13%
		Edema of legs	10%
		Nerve paralysis	5%

Dyspnea is the predominant symptom. About one-half of the patients have a cough, and one-half of these have sputum, which is hemorrhagic in one-third. Pain is present in one-third of the cases. It is noncharacteristic and is manifested in various locations, usually retrosternal or the lateral costal, or in the back or the shoulder. It is not an early manifestation. Physical signs of an intrathoracic tumor are present in one-half of the cases; there is evidence by x-ray in one-third; external tumors in one-sixth. Various signs of intrathoracic pressure are observed in one-third to one-half of the cases; lymph node involvement in one-third. Pleural effusion, which was only once hemorrhagic, once purulent, and only once showed tumor cells, was present in one-sixth of the cases. Disturbance of the gastrointestinal tract and loss of weight and of strength were noted in a small series.

The clinical course of the disease is short; though it is difficult to know in the usual case just when the tumor develops. Death supervenes, except in the cases that respond to treatment, within a few months from the appearance of the symptoms, though it has come as early as four weeks and has been delayed as long as eighteen months. The immediate cause of death is usually suffocation at a time when, with no cranny left patent in the thoracic cage, the intrathoracic vessels and the respiratory passages are squeezed tight shut. At times metastatic involvement of the heart and lung or brain or spinal cord is the factor. Few patients succumb from exhaustion or toxemia or hemorrhage as is common in malignancy elsewhere.

Diagnosis.—As has been suggested, the diagnosis of thymic tumors is difficult to make before death and autopsy. There are no symptoms of chromaffin disturbance to point to thymus gland involvement. The clinical symptoms at first are few and nonpathognomonic, and not until lymph node enlargement or symptoms of intrathoracic pressure develop is the presence of the neoplasm suspected. If an individual develops dyspnea, with a dry, persistent cough which cannot be explained otherwise, intrathoracic neoplasm must be thought of. Great reliance must be placed on x-ray examination and bronchoscopy to confirm this, and to establish the location, whether mediastinal, bronchial, pleural, or pulmonary, and whether benign or malignant. Biopsy, carefully performed, of the accessible lymph glands may reveal the character of the growth and point out the prognosis as well as therapeutic indications.

Pulmonary tuberculosis, Hodgkin's disease, primary malignant growths of the bronchial and mediastinal lymph glands, substernal goiter, aneurysm and tumors of other than thymic origin must be differentiated.

Treatment.—Surgical. From this review of malignant thymic growths it is evident that surgery has a very limited scope in their treatment. Usually when the diagnosis has been established, the tumor has involved the chest wall or lymphatic glands to such an extent that complete extirpation is impossible. I can find no record of complete surgical removal of a malignant growth of the thymus. Several explorations have been made by anterior thoracotomy, and excision then was deemed impracticable. In one case the manubrium was split and was separated from the body of the sternum. This decompression seemed to relieve the dyspnea for a while. Thoracic surgery, however, has progressed technically to the point where removal of tumors localized to the thymic area may be undertaken successfully. The effort in selected cases is justifiable.

Radiotherapy. A number of thymic tumors are radiosensitive, particularly the lymphosarcoma type. With high voltage radiation, or radium emanation, or radium pack, many lymphosarcomas will regress and even disappear. Repeated radiation in cycles is required at inter-

TABLE III

REPORTED BY	DIAGNOSIS	ESTABLISHED BY	AGE	SEX	DURATION OF SYMPTOMS	DATE OF BEGINNING OF TREATMENT AND TYPE NUMBER OF TREATMENTS MO./YR.	RESULTS
1. Janeway, 1920[11]	Thymoma	Autopsy	48	F	9 months	11/16 Radium 2 series	Death in 3 months, February, 1917.
2. Janeway, 1920[11]	Thymoma, giant cell	Autopsy	32	M	2 years	1/ 5 X-ray 56x	Regression and death. Hemorrhage, May, 1917; 2 yr. 4 mo.
3. Janeway, 1920[11]	Lymphemia-lymphocytoma	Autopsy	8	M	3 months	2/19 Radium 1x	Death 24 hours. Radium poisoning.
4. Janeway, 1920[11]	Thymic tumor	Autopsy	25	M	4 months	1/19 Radium 1x	Death from asphyxia, January, 1919.
5. Janeway, 1920[11]	Thymic tumor	Not proved	12	M	2 months	12/18 Radium 1x; Intravenous 1x	Death in 3 months, March, 1919.
6. Janeway, 1920[11]	Thymic tumor	X-ray and clinical picture	29	M	7-8 months	12/17 Radium 2x	Regression and death in 14 months, acute infection, March, 1919.
7. Janeway, 1920[11]	Thymic tumor	X-ray and clinical picture	14	F	7 months	2/18 X-ray 15x	Regression. Well 1 year. Death, September, 1921.
8. Janeway, 1920[11]	Thymic tumor	X-ray and clinical picture	20	M	9 months	Radium 3x followed by x-ray 5x	Regression. Well 1 year. In bed, extremely ill, March, 1921.
9. Janeway, 1920[11]	Thymic tumor	X-ray and clinical picture	?	M	9 months	Radium 2x	No effect. Death November, 1919.
10. Groover, 1925[12]	Thymic tumor	X-ray and clinical picture	39	F	6 months	9/24 X-ray 4x; tonsil ulceration	Regression. Lost sight of. Unfavorable, July, 1925.

TABLE III—CONT'D

REPORTED BY	DIAGNOSIS	ESTABLISHED BY	AGE	SEX	DURATION OF SYMPTOMS	DATE OF BEGINNING OF TREATMENT AND TYPE NUMBER OF TREATMENTS MO./YR.	RESULTS
11. Groover, 1925[12]	Thymic tumor	X-ray and clinical picture	61	M	2 months	12/24 X-ray 1x	Regression 1 month. Well February, 1934.
12. Pool, 1925[13]	Thymic tumor	—	33	M	9 months	9/23 X-ray 3 series; 4x and 2x	Regression. Well March, 1926. Lost sight of.
13. Dwyer, 1927[14]	Thymic tumor	Not proved	42	M	1 year	9/24 X-ray 3x	Regression to August, 1925. Well since 11/24.
14. Doub, 1930[15]	Lymphosarcoma	Biopsy gland of neck	38	M	?	8/24 X-ray multiple x	Regression. Recurrence 4 times. Death, 1932.
15. Doub, 1930[15]	Thymoma	Biopsy gland of neck	39	M	6 months	2/28 X-ray 3x	Regression. Death, November, 1930.
16. Doub, 1930[15]	Lymphosarcoma	Biopsy of tumor	25	M	2 weeks	1/29 Radium needles 1x; X-ray 2x	Regression. Death, March, 1931.
17. Doub, 1930[15]	Lymphosarcoma	Biopsy gland of axilla	37	F	1 year	4/29 X-ray 1x	Regression. Living. Still taking treatments.
18. Doub, 1930[15]	Thymoma, pulmonary tuberculosis	Biopsy of tumor	32	F	3 months	5/25 X-ray 1x	Regression. Death in 2 months.
19. Craver[16]	Thymic carcinoma	Autopsy	39	F	1 year	1/28 X-ray 26x; Radium 16x	Death from metastasis March, 1930. Regression of tumor at primary site.
20. Craver[16]	Thymoma	Clinical picture	39	M	6 months	3/28 X-ray 61x	Death September, 1931. Metastasis. Primary tumor regression.

vals of one month. Metastases must be watched for, and be appropriately irradiated. Table III gives a record of twenty patients treated by radiation.

Late reports of these patients have been sent to me by the attending physicians. Two (10 per cent) are known to be living and well for a ten-year period. One is living but still under treatment at five years. Fourteen (70 per cent) are known to have died. Three (15 per cent) were unimproved or lost sight of. In fifteen cases a very definite regression or disappearance of the tumor was noted at first; in five no helpful effect; in one only a harmful effect. Death came in the known fatal cases from three months to eight years, with usually a reappearance of the growth. From these figures it may be inferred that although thymic malignancies will respond to radiotherapy favorably for a time, a small percentage of these will permanently disappear. Only patients with lymphosarcoma types of malignancies are favorably influenced or recover. Carcinoma of the thymus will be 100 per cent fatal unless surgery can successfully remove the growth.

CASE REPORTS

CASE 1.—J. G., male, aged fifty-seven years, was admitted to Presbyterian Hospital March 27, 1932, on account of a progressively suffocating dyspnea of three days' standing. He had been well until December, 1931. Then he noticed a small lump on the right side of his neck. This enlarged rapidly in January, 1932. The tumor was treated by x-ray therapy in a hospital clinic, where a tentative diagnosis of either tuberculosis or sarcoma of the cervical lymph glands was made. Treatments were given over the right side of his neck December 29, January 13, January 26, and February 10 with 150 r. With this treatment the mass was said to have become more mobile and smaller, and his weight increased from 139 to 144 pounds. The patient, himself, did not feel that he was better and discontinued attendance at the clinic. About March 13 he developed headache and dizziness. There was an occasional cough with sputum that suggested a content of blood and pus. Then rather suddenly he became hoarse and dyspneic and developed dysphagia. There was loss of weight, and the mass in his neck was becoming larger and slightly painful.

Past History: He had always been well and strong, except that in 1914 he had had a fracture of the left leg, which was said to have been complicated by a tuberculous infection of the knee joint and resulted in an amputation through the middle of the thigh. Five children are all living and well. His father had died of a cerebral hemorrhage; his mother of senility.

Physical Examination: On admission to the hospital the man was orthopneic. There was slight general cyanosis accentuated in the face and neck. There was extensive dental caries. Tonsils were not enlarged. Marked edema and redness of the right pharynx were sufficient to obstruct the fauces and interfere with laryngeal examination. The tongue was slightly coated. He could not speak above a whisper.

Cervical tumor: There was a hard fixed mass in the supraclavicular region, the size of an egg; slightly irregular and nodular, and slightly tender. The cervical lymph nodes were slightly enlarged, bilaterally, and independently of the mass on the right side. Heart action was regular, and of good force, 100 per minute. Pulse was of fair volume. Vessel walls were slightly thickened. Respirations were stridulous,

26 per minute. Breath sounds were heard throughout the chest with diminished intensity. A few faint subcrepitant râles were present at the bases. No abnormal dullness was found anywhere in the chest. Temperature was 101° F. The liver edge was felt just below the costal margin. Left lower limb had been amputated in the middle of the thigh. Reflexes were normal.

Laboratory Findings: Urinalysis: 1.030; acid; a trace of albumin; occasional finely granular cast; occasional red blood cell. Blood count: red blood cells 4,600,000; Hg. 90 per cent; white blood cells 13,200; polymorphonuclears 78 per cent; small mononuclears 16 per cent; large mononuclears 6 per cent. Wassermann and Kahn tests negative.

X-ray examination March 30 of the chest by Dr. G. W. Grier showed a large mass in the superior mediastinum above the arch of the aorta. There was no evidence of metastasis in the lungs.

Fig. 1.

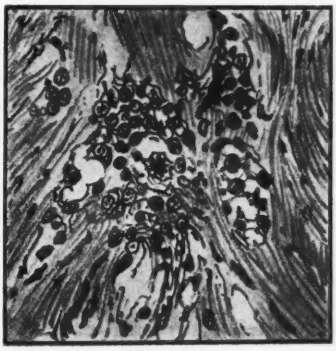

Fig. 2.

Fig. 1.—Case 1. Carcinoma of thymus gland with metastasis.

Fig. 2.—Case 1. Carcinoma of thymus. Small, darkly staining cells resembling lymphocytes, with occasional atypical mitoses. These are arranged in islands, held in a dense fibrotic stroma.

Biopsy: On March 31 a nodule was removed from the mass in the neck. Report on the pathologic condition by Dr. Wallhauser: microscopy: "Nests of polygonal cells with hyperchromatic nuclei, surrounded by rather dense and extensive fibrous stroma. Some areas are degenerated and even suggest calcification. The appearance is that of thymic carcinoma. I believe it to be slowly progressive in type."

Direct laryngoscopy by Dr. Ellen J. Patterson April 19: right side of the larynx was a mass of edematous tissue. Left side was also edematous. Ventricular bands were in apposition. It was impossible to see cords. There was intense inflammation.

On the advice of Dr. E. D. Boaz, consulting laryngologist, a tracheotomy was done under local anesthesia soon after admission. This gave the man instant relief from the dyspnea. He was able to obtain his first sleep in three days' time. Temperature, pulse, and respirations became normal in one week's time. Hoarseness in the

voice mitigated in two weeks, but did not clear. The mass in the neck became larger. Surgery and further radiotherapy were considered impracticable. He was discharged from the hospital April 27 to be cared for at home by his family physician. Death occurred August, 1932, from asphyxia. Autopsy was not obtained.

Comment.—In this case of carcinoma of the thymus, glandular enlargement in the neck was the first symptom. The significance of this was not realized by the patient's first medical advisers. Tracheotomy relieved him temporarily of the asphyxia and of symptoms due to tracheal compression. Probably at no time in this case would surgery have been feasible.

CASE 2.—W. O'B., male, aged thirty-five years. Onset in December 5, 1932, with an attack of tonsillitis and influenza. He improved sufficiently to be out of bed, but had a relapse with exacerbation of cough and sputum which became foul. Patient had lost thirty-two pounds in weight; otherwise he felt well. Eighteen years before he had had a gonococcus urethritis. He used alcoholics in moderation with an occasional overindulgence. His father had died at sixty-nine years following an operation for growth in the rectum. His mother had died at the age of sixty years, of a cerebral hemorrhage. Patient was married, and had two children living and well. A diagnosis of lung abscess was made, and the patient was sent to Dr. Ellen J. Patterson at the Presbyterian Hospital for bronchoscopy.

Examination.—On admission to the hospital February 4, 1933, temperature was 99°; pulse 124; respiration 28. Nutrition fair. Muscular development good. Seven teeth were carious. Tonsils were small and cryptic. Cervical lymph nodes were slightly enlarged.

Chest: Limitation of motion in the right upper chest. Dullness, cavernous breathing, large moist râles, increase in vocal and tactile fremitus over the right lung, anteriorly and posteriorly as far as the fourth rib. Left lung clear, but hypertrophied. Heart displaced to the left. Action regular but not forceful. There was no evidence of vascular disease. Abdomen was normal. Extremities were normal.

Laboratory Findings: Hemoglobin 78 per cent; red blood cells 3,900,000; white blood cells 19,000; polymorphonuclears 78 per cent; eosinophiles 1 per cent; small mononuclears 18 per cent; large mononuclears 7 per cent; mast cells 1 per cent; Wassermann and Kahn tests negative. Urinalysis: 1.015; acid; a faint trace of albumin; occasional red blood cell. Sputum: Culture showed small gram-negative bacilli. Many cocci in long chains, morphologically influenza and streptococcus pyogenes.

X-ray examination February 5 showed cavitation in the right upper lobe 1.5 inches in diameter with extensive consolidation of the lung around the cavity; a collection of fluid in the interlobar fissure between the right upper and the right middle lobes; consolidation of the right lower lobe suggesting pneumonia.

Bronchoscopy on February 7 disclosed pus lying in the pharynx; trachea below the vocal cords; intense inflammation of the tracheal mucosa which bled easily on touching. Small amount of pus from the right upper lobe. Bronchial mucosa had the appearance of being covered with granulation tissue in this location.

X-ray Examination: February 24, right upper lobe was almost solid. Two large cavities were present. Some pus lay in the interlobular fissure between the upper and the middle lobes. Consolidation in the right lower lobe seemed to be calcifying. There was an area 2 inches in diameter along the lateral chest wall where another abscess was in the process of formation.

Clinical Course: The patient was acutely ill, with a septic temperature ranging from 98° to 102°; pulse 100 to 130; respirations 20 to 30. There was some

dyspnea, frequent cough, and profuse, foul sputum totaling on some days 690 c.c. On February 24 I saw the patient in a consultation. External drainage of the upper lobe abscess was advised. This operation was done under novocaine anesthesia on February 27. Two and one-half inches of the third and fourth ribs were resected in the axilla. A large abscess cavity lay peripherally in vertical position; at least one-half the width of the lung with numerous bronchial openings with two small secondary abscess cavities adjacent. The cavity contained 1.5 ounces of pus. Much pus exuded into the cavity from the bronchi. The abscess cavity was unroofed and was packed loosely with acriflavine gauze.

Following the operation there was improvement in the patient's condition. Temperature became normal, pulse slower and stronger. There was free drainage from the lung. Cough and sputum became markedly diminished. Dyspnea persisted in a way that could not be accounted for. March 10 a number of moist râles developed at the base of the left lung. X-ray examination disclosed almost com-

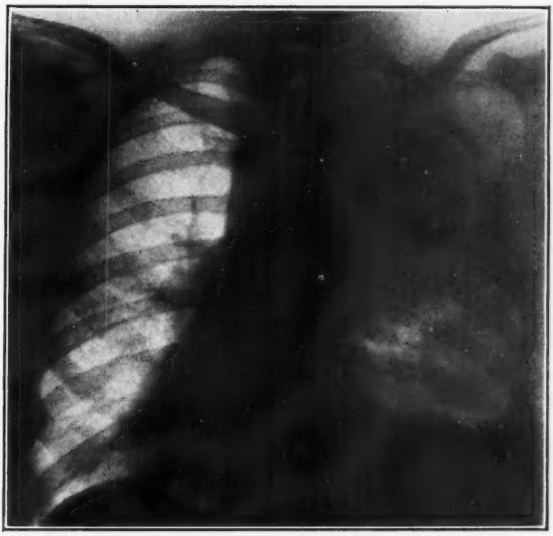

Fig. 3.—Case 2. X-ray picture showing carcinoma of thymus gland complicated by pulmonary suppuration.

plete consolidation of the right lung except for a small aerated area in the lower lobe; extensive infiltration in the left lung was suggestive of tuberculosis; increase in the amount of pus in the abscess cavity in the right upper lobe. Dyspnea became aggravated in spite of blood transfusion and oxygen. Death occurred March 15.

Autopsy: Thorax: Right pleural cavity free and clear, and the lung occupied its normal position and contained air. A large grayish mass 10 by 5 cm. of rather firm consistency occupied the space from the suprasternal notch to the level of the fourth rib. Heart: Normal in size, shape, and position. Pericardium free and clear; contained about 20 c.c. straw colored fluid. Lungs: Left lung normal in shape and size, with a moderate amount of anthracosis and a very moderate amount of congestion and edema of the base. Scattered throughout its substance were numerous, small, rather dense nodules, somewhat spherical in shape and on section showing a grayish homogenous appearance. The lymph nodes at the hilus were moderately anthracotic, quite dense and enlarged, and showed grayish, rather

friable surfaces on cut section. Some of these nodes were about 1 cm. in diameter. The pleura was glistening and smooth. No evidence of tuberculosis. The right lung was firmly bound down especially over the lateral, inferior, and posterior surfaces. Surgical incision in the axilla communicated with a large ramifying cavity situated in the middle lobe, and a ramifying abscess cavity of the upper lobe. There was a large walled-off empyema over the surface of the diaphragm and the base of the lung. This had penetrated posterior to the pleura and extended below the diaphragm to the level of the upper pole of the kidney, and upward to the level of the fifth rib posteriorly. It contained about 700 c.c. of foul, yellowish, rather thin pus. Trachea: The trachea was compressed at the level of the suprasternal notch by the tumor mass. The tissue about the trachea was quite dense and fibrotic; it showed numerous circumscribed areas of neoplastic tissue. This was whitish in color and was inclined to be somewhat friable. When the tumor mass was excised posteriorly, a ramifying cystic cavity was seen to occupy the lower portion. Kidneys: Both kidneys were normal in shape and size. In the left kidney were two small, whitish metastatic nodules. Liver was possibly a little enlarged; of a pale brown color, and showed small metastatic nodules of a whitish color and firm consistency. These were scattered throughout the parenchyma.

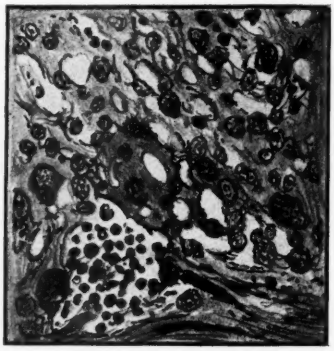

Fig. 4.—Case 2. Carcinoma of thymus. A Hassall's corpuscle is shown, with an adjacent focus of lymphocytes, much in the manner of the normal cycle of this element. The other cells resemble reticulum cells and lymphocytes. Occasional large, hyperchromatic Sternberg-like cells are present.

Microscopic Examination: The neoplasm consisted essentially of large, rather cuboidal and polygonal cells with rather small, clear nuclei containing chromatin. Some areas showed a sheetlike method of growth, while others showed a tendency toward small and large alveolus formation. Interspersed throughout the neoplastic tissue were numerous areas of focal lymphatic infiltration. Numerous atypical nuclei, some very large, showing numerous atypical mitotic figures were seen. Occasional bodies resembling Hassall's corpuscles were present. Fibrosis was a moderate feature. Some small areas of necrosis were present. Liver: The liver showed advanced, fatty infiltration and degeneration with numerous foci of lymphocytes. The metastatic nodules showed essentially the structure as above described. Lung: Metastatic nodules in the lung had essentially the same structure as described above. Kidneys: The smaller vessels of the kidneys were somewhat congested. The glomeruli were somewhat edematous, and there was some desquamation of the endothelium. The tubules showed cloudy swelling and contained some débris. Diagnosis: Thymic carcinoma with metastasis.

Comment.—This case is one of carcinoma of the thymus gland with metastases to the left lung, and liver and bronchial lymph glands, and was discovered only at autopsy. The clinical picture was obscured by the presence of extensive pulmonary suppuration in the right lung, and a basilar empyema with a retroperitoneal extension, which was not drained, and which was thought before death to be a pneumonitis of the lower lobe. This and the tracheal compression and metastatic involvement of the left lung were the factors in the rapidly progressive dyspnea which was the predominating clinical symptom.

CONCLUSIONS

I have presented a review of the pathologic findings in a group of cases, a review of the symptomatology in one hundred cases, and a report of two new cases of carcinoma with somewhat unusual features.

Diagnosis is most difficult to establish at an early time.

Successful removal by surgery is directly dependent upon being able to attack the growth when it is small and localized; so opportunity at best is offered only in a very small percentage of cases.

If surgery is impracticable, it is wise to give radiotherapy to all tumors in the thymic region.

Radiotherapy will cause regression or disappearance of the thymic tumor in a large percentage of lymphosarcomas. A few of these patients will remain well. Carcinomas are radioresistant.

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BRONCHIECTASIS

A Study of 100 Proved Cases

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ANATOMICAL distortion of the lung from any cause, characterised by bronchial dilatation, is called bronchiectasis. It is evident that bronchiectasis must always be a secondary condition, except in those very rare cases in which congenital malformation may play a part. By far the commonest type of bronchiectasis, however, follows repeated trauma and infection. In the present state of our knowledge, this type cannot be definitely attributed to a specific cause, and in this paper is called general bronchiectasis. One hundred cases of this syndrome have been collected and carefully analysed.

Each case has been proved by intratracheal injection of lipiodol, or at postmortem. Especial care has been taken of this, because the impression exists, and appears to be founded on fact, that deductions from previous series of bronchiectasis have been to some extent vitiated, because some of these cases were not bronchiectasis but fibrosis of the lung. Until the introduction of lipiodol it was not possible to distinguish accurately between these two conditions until a rather late stage, and at one time it was thought that bronchiectasis never existed without an antecedent fibrosis.

An attempt has also been made to elicit the early symptomatology of general bronchiectasis.

STATEMENT OF MATERIAL INVESTIGATED

Cases of general bronchiectasis	100
Cases of tuberculous bronchiectasis	9
Cases of bronchiectasis due to lung abscess	5
Cases of bronchiectasis due to carcinoma (primary)	2
Cases of bronchiectasis associated with empyema	4
Cases of bronchiectasis due to aneurysm	1
Cases of bronchiectasis due to syphilis	1
Cases of bronchiectasis due to monilia infections	1
Cases of bronchiectasis due to industrial pneumokoniosis	1
	124

SUGGESTED CLASSIFICATION, by antecedent conditions.

Congenital.

Defects in development, and following "residual" areas of atelectasis.

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Received for publication, March 8, 1935.

Acquired.

(A) General Infections.
- (a) General.
- (b) Lung abscess.
- (c) Empyema.
- (d) Paranasal infection.

(B) Special Infections.
- (a) Tuberculosis.
- (b) Syphilis.
- (c) Monilia infections.
- (d) Echinococcus infections.

(C) Causes Primarily Mechanical. (Secondarily Infective.)

I. Outside a Bronchus.
- (a) Secondary malignant tumors.
- (b) Aneurysm.
- (c) Glands, enlarged, usually tuberculous.
- (d) Fibrosis (nontuberculous).

II. Inside a Bronchus.
- (a) Foreign body.
- (b) Bronchial carcinoma.
- (c) Non malignant tumor.
- (d) Inspissated plugs of mucus and fibrinous plugs, e.g., in diphtheria.

GENERAL GROUP

It will be seen that 100 cases belonging to this group have been collected.

It is not generally agreed as yet whether influenza of the epidemic type, such as was seen in 1890 and 1918, should be regarded as a specific infection due to the Pfeiffer bacillus. In these circumstances, the cases which have this disease as an antecedent factor have been kept in the general group and not placed under the heading of special infections, though it seems possible that this arrangement may have to be modified later.

AGE INCIDENCE

It will be noticed that 64.5 per cent of the children presented for treatment between the ages of 5 and 15 years. In order to determine, as far as possible, the age of greatest liability to infection, the notes have been carefully scrutinised to trace when the child was first infected. It is realised that such evidence is uncertain and not absolutely reliable, but the figures obtained are worthy of note.

The average age of apparent infection in the 0 - 10 group was 2.3 years, and the same factor in the 10 - 20 group was 5.25 years. As far as can be ascertained then from such evidence, a very high proportion of cases of childhood nontuberculous lung infection is contracted between the ages of 2 and 5 years. These appear to be the "danger" years.

The peak years in adult cases are between 40 and 50, the average age of all adult cases being 42.8 years.

TABLE I

AGE INCIDENCE

CHILDREN						
0 – 5.	8 cases	average	age	at	onset	2.1	16.7 %
5 – 10.	16 cases	"	"	"	"	2.5	33.4 %
10 – 15.	15 cases	"	"	"	"	4.7	31.15%
15 – 20.	9 cases	"	"	"	"	5.8	18.75%
	48						
ADULTS							
20 – 30.	9 cases					17.3%	(Probably include some childhood cases.)
30 – 40.	11 cases					21.1%	
40 – 50.	20 cases					38.5%	
50 – 60.	8 cases					15.5%	
60 – 70.	3 cases					5.7%	
70 – 80.	1 case					1.9%	
	52						

Average age for all adult cases 42.8 years.

Taking all cases together, 64 per cent of all cases of bronchiectasis occur before the age of 20 and between 40 and 50, the disease being uncommon between 20 and 40, and rare after 60.

TABLE II

GROUPING ALL CASES TOGETHER

0 – 10	24%
10 – 20	20%
20 – 30	13%
30 – 40	11%
40 – 50	20%
50 – 60	8%
60 – 70	3%
70 – 80	1%

Group 20 – 30 probably includes some childhood cases.

The figures do not quite represent the true state of affairs, as it is exceedingly probable that of the 13 per cent of cases occurring between 20 and 30, some are childhood cases.

TABLE III

	DR. B. KING'S SERIES	THIS SERIES
0 – 10	1.6%	24.0%
10 – 20	23.3%	20.0%
20 – 30	25.0%	13.0%
30 – 40	26.6%	11.0%
40 – 50	13.4%	20.0%
50 – 60	4.0%	8.0%
60 – 70	3.4%	3.0%

It is of interest to compare these figures with Bastian's, who found that over 60 per cent of his cases occurred after the age of 60 years.

Extracts by Dr. D. Barty King from the records of the Brompton Hospital are taken for comparison (Table III).

Powell and Hartley say, with regard to Barty King's figures: "Incidence of the disease in the first decade of life is probably underestimated, owing to the fact that the number of children admitted to Brompton Hospital is limited."

SEX INCIDENCE

It is generally agreed that males show a slightly higher incidence than females, and the figures here agree with this. (Table IV.)

Miller, however, in 22 cases, found only 8 males to 14 females, i.e., 64 per cent females and 36 per cent males.

TABLE IV

SEX INCIDENCE IN GENERAL BRONCHIECTASIS

All cases together:		Males	55%
		Females	45%
Children:	48 cases	Males	27 – 56.3%
		Females	21 – 43.7%
Adults:	52 cases	Males	28 – 53.8%
		Females	24 – 46.2%

DISTRIBUTION OF LESIONS

No case has been seen which showed a purely apical distribution. A good many cases were seen in which the upper lobe of the lung was affected, but in all cases the lower lobe showed infection also. Four cases showed very marked involvement of the upper lobes, and one case showed a collapsed bronchiectatic upper lobe. (Table V.)

TABLE V

	THIS SERIES	MILLER'S SERIES	POWELL & HARTLEY'S SERIES
Right lung	25.0%	22.7%	37.0%
Left lung	43.0%	59.0%	
Bilateral	32.0%	13.9%	63.0%

ACUTE CASES

Chaplin, quoting 200 cases (many of them cases of old fibrosis), says that he found acute attacks mostly in the third and fourth decades.

In this series, out of eight acute cases, there were: first decade, 1; third decade, 2; fourth decade, 2; fifth decade, 1; sixth decade, 2.

ANTECEDENT CONDITIONS IN THESE CASES

Measles——2 cases.
Whooping cough——the same 2 cases.
Bronchopneumonia——4 cases.
One attack of pneumonia——2 cases.

CLUBBING

Thirty-five patients showed clubbing of the fingers, in two of these patients the toes were also affected.

On the other hand, 5 out of 8 cases of acute bronchiectasis showed clubbing, which represents 62.5 per cent. Of all cases of this disease, 35 per cent only show clubbing as mentioned above.

It is of some interest that of eight acute cases occurring in this series, no less than five patients showed clubbing.

The relationship of clubbing to the duration of the disease is shown below:

	Adults	*Children*
Average duration of a case of chronic bronchiectasis coming under treatment	6 years	4 years
Average duration of such a case with clubbing	9.4 years	8.3 years

The clubbing of toes was not seen alone.

DURATION OF THE DISEASE

On coming under treatment:

Adults	6 years
Children	4 years

Of th se who died:

Adults	14 years
Children	9.2 years

Table VII shows the antecedent conditions in the general group and Table VI gives a comparison of these figures with those of the late Dr. Clive Riviere's.

TABLE VI

	DR. RIVIERE'S	THIS SERIES
Measles	9%	11%
Whooping cough	25%	7%
Both	6%	14%
Bronchopneumonia	18%	15%
Bronchitis	18%	4%
Diphtheria	6%	Nil
Lobar pneumonia	12%	Nil
Congenital atelectasis	6%	Nil

The remainder of cases in this series come under other headings.

Twenty-eight patients gave a history of recurrent attacks, usually called "pneumonia," after the disease was established, and these 28 patients had 48 such attacks.

HAEMOPTYSIS

Eleven per cent of the cases had a single fairly large haemoptysis, 13 per cent had repeated haemoptyses, and 14 per cent had "streaky" haemoptyses.

Therefore, 24 per cent, or roughly a quarter of the cases, had frank large haemoptyses.

TABLE VII

ANTECEDENT CONDITIONS IN THE GENERAL GROUP OF 100 CASES

	NO. OF CASES	CHILDREN	ADULTS	REMARKS
Measles	16	11	5	
Whooping cough	2	2	Nil	
Both the above	14	12	2	One age 29
Bronchopneumonia	15	14	1	and one 40
One attack of an acute lung infection	18	Nil	18	
Winter cough	10	Nil	10	
Influenza (1918)	7	Nil	7	
Bronchitis with sputum	4	4	Nil	
Pyrexia of long duration	1	1	Nil	
Gas poisoning	2	–	2	
After childbirth	1	–	1	
After gastric operation	1	–	1	
No previous history	9	4	5	

Thirty-eight per cent of the patients had blood in the sputum at some period of their illness.

This series is compared with Acland's in Table VIII.

TABLE VIII

	ACLAND'S SERIES	THIS SERIES
None	20%	62%
Streaky	32%	14%
Frank	48%	24%

EARLY SYMPTOMATOLOGY

In order to determine the early symptomatology of bronchiectasis, all patients with the established disease have been carefully questioned as to what was the first sign of anything unusual in their case, and Table IX has been constructed from their answers.

TABLE IX

	ADULTS	CHILDREN
Cough	36	32
Pyrexia	7	4
Cough and sputum	2	3
Dyspnoea	3	Nil
Haemoptysis	Nil	6
Night sweats	Nil	1
Nasal catarrh	1	Nil
Loss of weight	Nil	1
General ill health	Nil	1
Pain in chest	3	Nil

Sixty-eight per cent of all patients started their disease course with cough, and this symptom is fairly evenly divided between children and adults.

Five per cent of the patients commenced their course with cough and sputum, and in these cases sputum formed a large part of the picture from the commencement.

It seemed that this apparently silent development of the disease, with sudden declaration of the complete syndrome, should be accompanied by a reduction in the expected duration of life. As far as can be ascertained, however, from a limited number of such cases, no prognostic significance can be deduced.

	All Cases
Average duration of disease on coming under treatment	5 years
Without sputum	2.3 years
With sputum	2.3 years
With much offensive sputum	7.8 years
With much nonoffensive sputum	7.8 years

It seems quite clear that those patients who present for treatment with a great deal of sputum, have had a longer disease course than those without or with only a trace of sputum.

The factor of offensiveness does not appear to depend on the length of the disease, but on other considerations.

CASES WITHOUT COUGH

Ninety-six per cent of the patients had a cough at recurring periods during the development of the disease, and it will therefore be of interest to analyse the four cases which remain.

One was an adult, and the other three were children.

The adult was twenty-eight years old and dated his disease from an attack of whooping cough when he was four years old. His parents said that the whooping cough had lasted for nine months, and appeared to clear up completely at the end of that time. After an interval of six months, it was noticed that the child's breath was offensive, and that occasionally he was sick, bringing up a quantity of evil smelling fluid. The disease remained undiagnosed for many years, and the child had to be removed from school at the request of the headmaster because of these attacks. In 1926, his chest was x-rayed, as part of the routine examination in the course of a barium meal. Bronchiectasis was diagnosed from the film, and, after confirmation with lipiodol, an artificial pneumothorax was done, later followed by a phrenic avulsion. The offensive odour has disappeared, and he no longer has his attacks of vomiting.

The first child was a male aged four years, and his only complaint was that he had recurrent attacks of pyrexia, for which no cause could be found. He came to the Royal Chest Hospital because his brother, who had bronchiectasis, was being treated there. This child had detelectasis of the right middle and lower lobes.

The second child was a female aged eleven years, and the only complaint was a state of general ill health. Bronchiectasis of a cylindrical type was seen by lipiodol injection.

The third child was a female aged three years, and the complaint was of pyrexial attacks. The same condition was found here, and while in the hospital, she developed a multiple arthritis of the joints of the hands and feet.

Although one adult is included in these four cases, it will be seen that if he had been seen as a child, he would still have been included.

It seems that cough always occurs in adult bronchiectasis but may not occur in this disease in childhood.

SPUTUM

The Table X shows the incidence of sputum in this series.

TABLE X

SPUTUM		ADULTS	CHILDREN	
None		5	14	19%
+			9	9%
++	offensive	24	9	33%
	nonoffensive	26	13	39%

LOSS OF WEIGHT

In nine cases there was a complaint of definite loss of weight. All these patients were adults, and it does not appear that loss of weight forms any part of the symptomatology in children.

Even up to a short time before a fatal issue, children seem to be well nourished, and in view of the very advanced suppurative changes found in the lungs postmortem, this is an astonishing feature. Adults, on the other hand, seem to have phases in which loss of weight is a very marked feature, and these phases do not apparently always correspond with an increase in the disease process, though occasionally the two do correspond.

It is comparatively easy to understand a loss of weight which is accompanied by a long continued pyrexia. Children are able to withstand changes in body temperature more easily than are adults, and so show less constitutional disturbance.

COMPLICATIONS OF BRONCHIECTASIS

Paranasal Infection.—That there is some relationship between lung infections and infection of the paranasal sinuses has long been apparent. In this series, however, only four cases of paranasal suppuration occur, all in adults. Further, all these occurred a long time after the lung infection was known to exist.

One patient developed a suppuration in the antrum of Highmore twenty-four years after his lung was infected, and another twenty years after. In both cases, operative interference apparently cured the nasal condition without any effect on the lung.

So far as can be judged from such a small number, paranasal conditions are secondary to the lung infection, and their appearance has no effect on the lung.

This condition, therefore, appears under the heading of complications of bronchiectasis.

Arthritis.—Only three cases occurred in the series, all in children.

The arthritis was multiple in its distribution and fleeting in character. Pain, swelling and limitation of movement characterised all three cases, but they all apparently cleared up completely, at any rate, as far as signs and function were concerned.

No case has come to autopsy.

Cerebral Abscess.—This complication has not occurred in the series.

Empyema.—In cases of bronchiectasis with empyema, it is difficult to determine whether the empyema occurred before the bronchiectasis or as a result of it.

Reference has already been made to this question.

In view of this, it has been considered advisable to leave this question, and to consider empyema as an occasional complication of bronchiectasis.

Bacteriology.—Forty-two patients were examined bacteriologically, with the following result:

Pneumococci (all types)	15
Micrococcus catarrhalis	11
Pfeiffer's bacillus	17
Streptococci	7
Staphylococci	1
Friedlander's bacillus	5
Leptothrix	1

Most of the cases showed a mixed infection, but where one type or organism predominated, the case has been placed under that type.

Pfeiffer's bacillus did not occur more frequently in the cases which were thought to have been caused by epidemic influenza than in other cases.

Detelectatic Bronchiectasis.—In a recent paper, attention has been drawn to the necessity of reserving the word "atelectasis" for congenital conditions, and the word "detelectasis" is introduced, with the reasons for doing so (Fletcher).

This condition is by no means an uncommon one, and 20 per cent of the cases investigated here showed collapse of a lobe.

Table XI gives full details of these cases, fifteen of which are children and five adults.

SUMMARY

It will be seen that eleven cases occurred on the left side and nine on the right side. It is generally the lower lobe that is collapsed, though in one case the upper lobe was affected.

The condition cannot be diagnosed with any certainty clinically; though the compensatory emphysema which occurs in the uncollapsed lobe may give a clue. The x-ray picture will generally show the line of the collapsed lobe, though sometimes if films are soft it may merge into the line of the diaphragm and not be seen.

TABLE XI

DETELECTATIC LOBES

20 CASES OUT OF 100: 15 CHILDREN AND 5 ADULTS

NO.	AGE	SEX	CLUBBING	FAMILY HISTORY OF PHTHISIS	SIDE	DURATION OF DISEASE (IN YR.)
3	16	Male	+	+	Right	15
4	9	Male	–	–	Left	7
7	12	Male	+	–	Left	7
13	13	Female	+	–	Left	12
21	31	Male	+	–	Left	11
25	13	Male	–	–	Right	6
32	37	Male	+	–	Right	2 –
47	4	Male	+	+	Right	2 –
54	46	Male	–	–	Right	5
58	4	Male	–	–	Right	Acute
59	6	Female	–	+	Left	5½
71	6	Male	–	–	Right	4
78	7	Female	–	–	Left	4
82	41	Female	+	+	Left	1
83	6	Male	–	–	Right	1
85	6	Female	–	–	Left	Acute
87	13	Female	–	–	Left	
90	13	Female	–	–	Left	12
95	29	Female	+	–	Left	10
96	2	Male	–	–	Right	1

There is no intention of discussing the question of these detelectatic lobes fully. It seems likely that some of them are congenital in origin.

Residual areas of atelectasis are especially liable to infection on account of their poor blood supply, and the normal respiratory movement is absent in these areas.

THE EARLY SYMPTOMATOLOGY OF BRONCHIECTASIS

Childhood Type.—Earlier in this paper has been given the result of an enquiry into the initial symptom noticed by patients suffering from bronchiectasis.

Thirty-two children out of forty-eight commenced their illness with a cough, and three started with cough and sputum.

Of these, twenty-five had suffered from an attack of measles or whooping cough, or both.

It is evident then that cough, by itself, is a serious symptom in children, and that measles and whooping cough are the precursors of a chronic or subacute lung infection in a very large proportion of cases.

In this connection, a small survey has been made of the after-histories of cases of measles and whooping cough, which had been complicated by bronchopneumonia.

Out of 35 cases traced, 17 were found to be suffering from chronic lung infections, and out of the same number, only five, or 14 per cent, were found to be in good subsequent health. (Leys.)

The period that elapses between the acute exanthemata and the development of the complete syndrome of the chronic lung infection varies. In some cases the process is apparently continuous, with no appreciable break; in others there appears to be a period of good health between the two. Sometimes this period may be as long as one year or even two.

The second great group of precursors of bronchiectasis in children are attacks which are generally termed "acute bronchitis" or "bronchopneumonia." An acute primary bronchopneumonia is a comparatively uncommon condition in childhood. Most of these attacks fall under four heads.

The first is the type described by Sharkey as "acute bronchiolectasis" or, as Box called it, "honeycomb lung." This condition, so far as it is seen nowadays, is generally fatal.

The second is the type described by Lord, Riesman, Larrabee, Miller, and others. Although there may be apparent widespread involvement of the lung tissue at the beginning, the inflammation in most cases becomes basal in distribution.

This is the common lung infection of childhood, and it is exceptional to see complete recovery.

Austrian, however, described one case in which the patient apparently recovered, and as we have seen, Miller described such a type.

The third group are the tuberculous bronchopneumonias. There are various grades and degrees of this type, but as they are all tuberculous in origin, they will not be described here.

The fourth group is a miscellaneous one. In any case, it is by far the smallest group of the four. It includes acute lung infections, involving all parts of the lungs equally, with very sharp rises of temperature and small remissions. They are often seasonal in origin and, if the patient survives for three or four days, generally terminate in complete recovery.

It also includes genuine cases of acute bronchitis, with robust defensive reaction.

The conditions we have described so far account for 39 out of 48 cases of bronchiectasis of the general type. Of these 39, 35 patients said that their disease started with a cough, and the other four said that it started with pyrexia.

Of the nine who are left, six commenced with a haemoptysis.

Haemoptysis in childhood seems to bear a graver significance than in adult life.

The other three cases started in various ways, which would be of no diagnostic help from the point of view of early symptomatology.

In childhood, then, the early symptomatology of bronchiectasis is that of its precursors.

Adult Type.—Out of 52 cases, it will be noticed that 18 patients developed their disease after one attack of an acute lung infection, 10 after winter cough, 5 after an attack of measles, and 7 after epidemic influenza. These four groups account for 40 of the 52 cases, and will be dealt with first.

Of the 18 who suffered one acute lung infection, 16 started with a cough, and two with cough and sputum.

The pneumococcal lobar pneumonia of adult life, seasonal in its incidence, typically abrupt in its invasion and in its defervescence, is not considered here. No case of chronic lung infection has been seen following this type of disease.

These illnesses which herald the onset of a chronic lung infection are called by various names, and the name used, generally speaking, depends on the part of the respiratory mechanism which bears the brunt of the infection. So we have such terms as pleurisy, acute bronchitis, bronchopneumonia.

Of the 18 cases mentioned here, 9 were called pleurisy, 7 were called pneumonia, and 2 acute bronchitis.

It will be noticed, however, that in 10 cases there was no history of an acute attack, the only antecedent condition being winter cough. It is of some interest that the incidence of cylindrical bronchiectasis was high in the cases that gave a history of winter cough only, and that of the saccular variety in the cases with an acute lung infection.

Apart from this, it seems of little moment, apparently, in the established syndrome of adult bronchiectasis, whether there has been an antecedent acute lung infection. And this is where the real difficulty lies. For, at present, there seems no way of foreseeing whether adult patients with an acute lung infection, or with a long history of winter cough, will develop bronchiectasis. So far, no case has been seen in which a simple pleurisy gave rise to bronchiectasis.

Five patients gave a history of measles, and this is a high proportion for adults. The opportunity has occurred on three occasions of seeing these attacks. They are exactly similar in every way to the usual pyrexial attacks which punctuate the course of the disease, with the exception of the rash, which, in the cases seen, resembled a true urticaria more than a measles rash.

It seems possible, then, that the high incidence of "measles" in both adult and childhood bronchiectasis may possibly be accounted for by the fact that some of these attacks are allergic in character.

In one case, the sputum was cultured, and the direct extract of the killed organisms was used for a skin test. There was a remarkable reaction, an erythema measuring 10 mm. across, with a raised oedematous edge, appearing in twenty-four hours.

Pyrexial attacks in the course of the disease are of two types.

The type referred to above is the common one, and it has already been noted that 28 patients gave a history of 48 such attacks.

Some of these took place while the patients were actually under observation in the wards, and in other cases patients presented and were admitted because of them.

Typically, there is catarrhal reaction in the smaller bronchioles, pleural involvement, and in general, temporary extension of the disease.

The second type is a true bronchopneumonia with a high temperature (up to 104°), with slight remissions.

Often the disease extends to the other lung, there are definite areas of consolidation, signs may extend high up into the upper lobe, and the picture is one of extreme toxaemia.

It may be that the second type is merely a more formidable infection than the first, but the impression is that the first type is due to a periodic sensitization, and the second to a definitely extending bronchopneumonia.

On several occasions it has been noticed that on recovery from Type 1 the signs have regressed to the original field of disease, while in Type 2 the final site of disease is more extensive than it was before.

SUMMARY

1. A statement of the material investigated is shown.
2. A classification of bronchiectasis is presented.
3. One hundred cases of the general type are fully analysed.
4. Details of the cases of detelectatic bronchiectasis are given.
5. The early symptomatology is discussed.
6. Pyrexial attacks in the course of the disease are divided into two types.

Finally, I have to acknowledge my indebtedness to the physicians on the staff of the Royal Chest Hospital for permission to publish the analyses of patients under their care.

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MULTIPLE INTERCOSTAL NEURECTOMY FOR PULMONARY TUBERCULOSIS*

Indications and Results

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WHEN in 1929 we advocated multiple intercostal neurectomy for certain cases of pulmonary tuberculosis, we stated that our experience was limited to experimental observations and to the use of the operation for only six human beings. During the five years that have passed since our first report was prepared, we have operated on 16 additional patients, of whom 14 have been followed for more than one year after operation. In this article we shall record the observations that we have made since our first article was prepared, and we shall report the present results of the operation in the 20 patients who have been observed for from one to six and one-half years.

INDICATIONS

In 1929 we tentatively advocated intercostal neurectomy for certain patients in whom pneumothorax had failed and who, for one reason or another, were not suitable risks for thoracoplasty. We also recommended intercostal neurectomy for some patients whose lesions were not sufficiently extensive to require thoracoplasty and yet who needed surgical assistance. Upon the basis of our more than seven years' experience with intercostal neurectomy we are firmly convinced of its value for these indications. In spite of the proved value of the operation in properly selected cases we have never felt that it has a wide field of application, as is evidenced by the fact that we have used it only 22 times during a period in which we have used phrenic paralysis, intrapleural pneumonolysis, extrapleural pneumonolysis, and thoracoplasty many hundreds of times.

There is a small group of patients with predominantly unilateral tuberculosis without cavitation, or with a cavity of not greater than 2 cm. or possibly 3 cm. diameter, who continue to have symptoms of active tuberculosis in spite of prolonged bed rest, attempted pneumothorax and phrenic paralysis, perhaps combined with scaleniectomy. Such patients need additional surgical assistance; only intercostal neurectomy and thoracoplasty are possibly effective for them. In five of our six patients belonging to this group, thoracoplasty was definitely

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Received for publication February 27, 1935.

contraindicated because of predominantly unstable, exudative unilateral or bilateral lesions. In the sixth patient we felt that the less radical operation of intercostal neurectomy would bring about healing of the lesions, which it did. Six (30 per cent) of our intercostal neurectomy patients belong to the group under consideration (Cases 1, 2, 11, 12, 16, 17). Two patients are apparently cured*; before operation one was classified as far advanced A* (FAA) and one as far advanced B (FAB). The condition of one patient is arrested; she was classified as moderately advanced A (MAA) before operation. Three patients (2 MAA; 1 MAB) are improved; one now has negative sputum but is still being kept in bed; two patients were much improved but positive

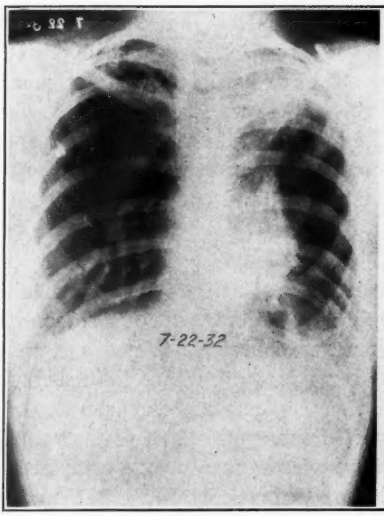

Fig. 1.

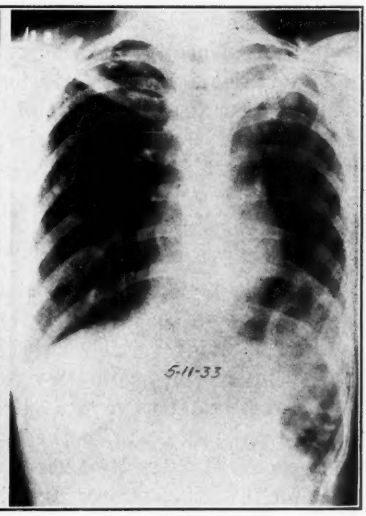

Fig. 2.

Fig. 1.—Case 12. Mixed productive and exudative lesions, possibly including multiple small cavities, twenty-three days before left multiple intercostal neurectomy. Sputum positive. Active tuberculosis for seven years, the last two and one-half of which were spent in a sanatorium, partly at bed rest. Phrenic paralysis had been produced two years before this roentgenogram was made, and pneumothorax had been lost because of adhesive pleuritis one year before. Multiple intercostal neurectomy was chosen for this patient as a definitive operation.

Fig. 2.—Case 12. Fibrosis and contraction of the lesions (note especially those in the first intercostal space) nine months after multiple intercostal neurectomy. Sputum negative. Patient out of bed four hours daily. Roentgenograms taken during the following year showed progressive fibrosis.

sputum and a probable small residual cavity required a thoracoplasty twenty-five months after the intercostal neurectomy operation in one of these patients. This patient now has a closed cavity and negative sputum. The second of these two has recently had the first stage of

*The National Tuberculosis Association's classification of the extent and severity of disease before operation and of the results after operation is used throughout this article. The final letter of the initialed abbreviations refers to the severity of symptoms, A being slight or none, B being moderate and C severe.

a partial thoracoplasty for residual cavity and positive sputum eighteen months after the intercostal neurectomy operation.

The most frequent indication for intercostal neurectomy is in those patients whose lesions are so extensive and whose cavities are so large that only thoracoplasty could reasonably be expected to bring about complete healing of the lesions and yet in whom thoracoplasty is at the time definitely contraindicated. There is no doubt but that a patient's postoperative reaction is much milder after intercostal neurectomy than after a stage of a thoracoplasty at which as few as two ribs are resected, mild though this reaction usually is. An exception to this statement occurs when the pleurae are so much thickened that virtually no respiratory movement of the underlying lung occurs after

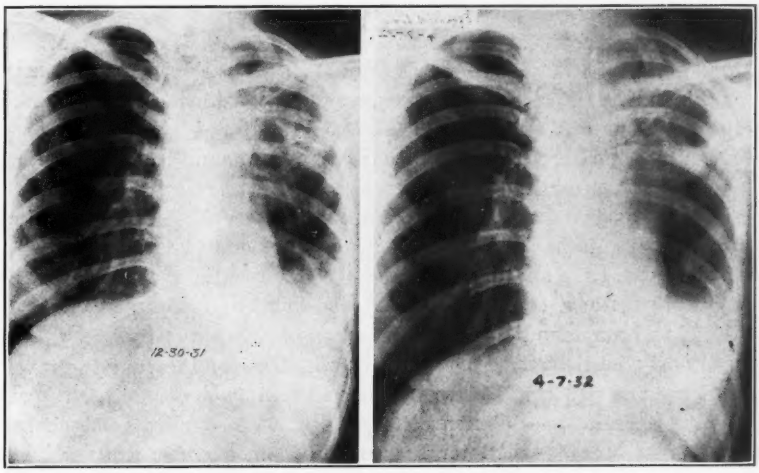

Fig. 3. Fig. 4.

Fig. 3.—Case 14. Predominantly exudative lesions with extensive cavitation twenty-five days before multiple intercostal neurectomy. Active tuberculosis for four and one-half years. A twenty-two-month-old pneumothorax had been lost two years before this roentgenogram was taken, and a phrenic paralysis had been produced ten months before. In spite of the anatomical indication for thoracoplasty, this operation was contraindicated because of the predominantly exudative lesions, fever, consistently rapid pulse, and active intestinal tuberculosis. A left multiple intercostal neurectomy was performed in order to prepare the patient for a thoracoplasty.

Fig. 4.—Case 14. Tendency toward fibrous transformation and absorption of the exudative lesions seventy-one days after multiple intercostal neurectomy. Two of the cavities have increased somewhat in size and the third has decreased in size. General condition of patient greatly improved, temperature practically normal, and pulse approximately 25 beats slower than before operation. A thoracoplasty was performed without incident; the cavities were completely closed and the sputum has remained negative; the patient is doing her own housework for three or four hours daily.

the thoracoplastic removal of ribs. In well-selected cases a primary intercostal neurectomy may cause sufficient improvement in the patient or his lesions, or both, to permit a later curative thoracoplasty. The most frequent reason that thoracoplasty could not be safely used at the time that we first saw the patients was that the lesions were

predominantly exudative and had recently manifested considerable instability. Furthermore, most of these patients had too many unstable lesions in the less diseased lung to permit the reasonably safe performance of thoracoplasty on the side of the more extensive lesions. Another circumstance that has occasionally caused us to choose intercostal neurectomy rather than immediate thoracoplasty is the presence of an unduly rapid pulse, which in these patients has been a manifestation of the toxic influence of the exudative lesions upon the myocardium. In a few patients whose lesions were not predominantly exudative but who were in decidedly poor general condition, we have successfully used intercostal neurectomy to improve the general condition sufficiently to permit the reasonably safe performance of a thoracoplasty.

We have used intercostal neurectomy preliminary to thoracoplasty in 12 (60 per cent) of our 20 patients (Cases 3, 6, 7, 8, 9, 10, 13, 14, 15, 18, 19, 20). One patient (FAA before operation) is apparently cured without thoracoplasty. Seven patients were improved; before operation one was MAA, one MAB, three FAA, and two FAB. Three of the patients have had thoracoplasty three, six, and thirteen months, respectively, after intercostal neurectomy; two are apparently cured and one has just had the thoracoplasty completed. Four of the improved patients have not had thoracoplasty; one of them has closed cavities, negative sputum, is beginning therapeutic exercise and will probably make a complete recovery without thoracoplasty; one patient has been found to have tuberculous tracheobronchitis, and thoracoplasty is, therefore, contraindicated. Two of the four improved patients are still confined to bed eleven and twelve months, respectively, after intercostal neurectomy with a reasonably good chance that thoracoplasty will later be possible; both of them are receiving pneumoperitoneum for intestinal tuberculosis, and the pulmonary lesions of both are definitely improved, one greatly so. One (FAB before operation) of the 12 patients was not improved by intercostal neurectomy; in spite of her poor resistance to tuberculosis a thoracoplasty was performed nine months after the intercostal operation on the desperate chance that her life might be saved; she died of gradual bilateral progression of the lesions sixteen months after the thoracoplasty. Three patients (all FAA) died eleven months, twenty months, and twenty-one months, respectively, after the intercostal operation from gradual progression of the tuberculosis; one of these patients had made so much improvement four months after operation that we believed that thoracoplasty would probably be safe after three more months of bed rest, but the patient became dissatisfied with the sanatorium life and left against advice five months after the intercostal neurectomy operation and died six months later. Another of the three

patients who died had severe diabetes; during the first two months after operation she improved, and then the bilateral lesions steadily progressed.

The complete success of the first three intercostal neurectomy operations that we performed in 1927 and 1928 caused us to believe that the operation might be of value as a last resort in almost hopelessly diseased patients. We used it with this in mind in only two (10 per cent) of our 20 patients (Cases 4 and 5). Before operation one was classified as FAB and one as FAC; the former died ten days and the latter twenty-two months after operation. We advise against the use of the operation for such desperately ill patients.

TECHNIC

The technic that we described in 1929 has been adhered to with the following exceptions:

1. The operation should usually be performed in two stages, a week or two weeks apart. Operation upon eight or nine intercostal nerves through the necessarily long incision under local anesthesia at one sitting occupies at least an hour, which may greatly fatigue patients who are as ill as are most of those for whom intercostal neurectomy is used.

2. The posterior 3 or 4 cm. of only the second to the sixth, inclusive, intercostal nerves should be resected; the seventh to the ninth or tenth, inclusive, nerves should usually be crushed and not resected because these are the motor nerves of the upper abdominal wall muscles. Although none of our patients who have had the lower nerves permanently or temporarily paralyzed has had any serious difficulty because of the paralysis of the upper abdominal muscles, we believe that temporary paralysis offers an element of safety, should dyspnea or great difficulty in expectorating occur. Two of our patients have had moderate difficulty in expectorating; they were relieved by the wearing of an upper abdominal binder. No case of severe dyspnea has been observed, but it is obvious that if intercostal neurectomy was performed upon a patient who was already even slightly dyspneic, or who had a low vital capacity before operation, severe dyspnea might develop.

3. We have in several cases followed our suggestion of 1929 to resect the scalene muscles in order to exclude from action all the muscles used in quiet inspiration. In most of our cases we have partially resected the serratus posticus superior muscle, and in all cases the phrenic nerve has been paralyzed—often several months before the intercostal operation was performed. When the phrenic nerve and the second to the ninth or tenth, inclusive, intercostal nerves have been paralyzed and the three scalene muscles partly resected, the

homolateral hemithorax becomes virtually immobile during quiet respiration and assumes the position of full expiration. In all our cases pneumothorax had been unsuccessfully undertaken, lost, or abandoned before the intercostal operation was performed.

RESULTS

Since the favorable effect produced by intercostal neurectomy depends upon pulmonary rest and only to a slight extent upon the moderate pulmonary relaxation (maintained expiratory position), the dramatically quick clinical improvement that is often seen after pneumothorax or thoracoplasty does not occur. Although we have occasionally seen a notable drop of the pulse rate and temperature within a week or two after operation, absorption and fibrosis of the lesions, closure of cavities, disappearance of tubercle bacilli from the sputum and improvement of the patient's general condition usually occur only gradually and are not clearly manifested until from two to six months after operation. We have repeatedly seen predominantly exudative lesions which had been behaving badly during unaided bed rest treatment, gradually undergo combined absorption and transformation into productive or fibrotic lesions following intercostal neurectomy.

In discussing the results of intercostal neurectomy emphasis must be placed upon the fact that the operation was chosen for the great majority of our patients because pneumothorax had failed on account of pleural adhesions and because of the character of their lesions, and because their past clinical course indicated an especially poor prognosis. The results in our 20 patients cannot, therefore, be properly compared with the results of other collapse therapy operations which are usually used for patients whose prognosis is not outstandingly bad. In 14 of our 20 patients sufficient improvement to permit the reasonably safe performance of a thoracoplasty was the best result that we expected.

In the section dealing with the indications for operation we have given the results for each group of patients, together with a statement as to the extent of the tuberculous lesions according to the classification of the National Tuberculosis Association. Since this classification considers only the extent of the pulmonary lesions and the severity of symptoms, and does not consider the prognostically significant exudative or productive character of the lesions, the classification is of little value in presenting a true picture of the type of patient with which we were dealing. The case histories to follow will assist the reader in classifying the patients for himself.

Without regard to the varied use of intercostal neurectomy as a definitive operation, as preparation for an intended thoracoplasty, or as a palliative operation of last resort, the results to the present time, or to the time when thoracoplasty was performed, together with the

National Tuberculosis Association's classification of our patients before operation, follow: Apparently cured, 3 patients (2 FAA, 1 FAB); arrested, 1 patient (MAA); improved, 10 patients (3 MAA, 2 MAB, 3 FAA, 2 FAB); unimproved, 1 patient (FAB); dead, 5 patients (3 FAA, 1 FAB, 1 FAC).

CASE HISTORIES

CASE 1.*—L. W., a woman, aged fifty-six years, had had pulmonary tuberculosis for more than eighteen months. At the time of admission to the University Hospital she complained of excessive cough, abundant sputum, weakness, loss of 31 pounds, night sweats, fever, and hoarseness. She was orthopneic, febrile, had from 15 to 150 gm. of sputum containing many tubercle bacilli, predominantly exudative infiltration (with some productive lesions) throughout the right lung with an infraclavicular cavity 4 cm. long, a few left apical lesions, and tuberculous laryngitis. Adhesions prevented induction of a right pneumothorax. During seven weeks' bed rest there was but little improvement in the general condition, and right phrenic paralysis caused only slight improvement. Thoracoplasty could not be safely performed because of the patient's poor general condition, her apparent age of sixty or sixty-five years and the predominance of exudative lesions. Right-sided intercostal neurectomy of the second to ninth nerves, inclusive, was done on November 29, 1927. The following March, tubercle bacilli permanently disappeared from the sputum, which varied from 10 to 20 gm. In April roentgenograms showed that the pulmonary lesions were predominantly productive, and there was no evidence of the cavity. The tonsils were removed and contained miliary tubercles. In April, 1929, this patient began to do her housework and in June, 1934, at the age of sixty-three years, she reported that she was well, had continued to work all day at her housework, was not fatigued, had no sputum or fever, that she had had no "colds," weighed 9 pounds more than at the time of operation and that she was dyspneic only when obliged to hurry. She is classified as apparently cured. Intercostal neurectomy, which was performed for this patient, was apparently responsible for her recovery.

CASE 2.—M. B., a woman, aged twenty-eight years, is known to have had pulmonary tuberculosis since March, 1925, though the disease probably began two years earlier. She was admitted to the University Hospital on November 9, 1927. She had been a bed patient since March, 1925. A clinically unsuccessful 30 per cent left pneumothorax had been induced and abandoned before admission.

At the time of admission she had 20 gm. of sputum daily, which was negative for tubercle bacilli. Roentgenograms showed no lesions in the right lung, but there were diffuse tuberculous infiltration in the upper half of the left lung and two small cavities and a questionable medium-sized one.

On November 10, 1927, a left phrenic paralysis was produced. This was followed by some improvement in the cough and a slight decrease in the amount of sputum. On several occasions the patient was got gradually out of bed so that she could go to the dining room for one meal a day; each time this increased physical activity caused fever, and the patient was again placed upon strict bed rest. It was apparent that the patient needed additional surgical assistance. Although a thoracoplasty would undoubtedly have been effective, the less severe operation of intercostal neurectomy seemed likely to be sufficient. On February 8, 1928, the posterior portions of the second to the tenth left intercostal nerves were resected. Forty minutes after the beginning of the operation the patient suddenly developed epilepti-

*Cases 1 to 6 were reported in 1929 by Alexander. The histories are here brought up to date.

form convulsions, which persisted for about three minutes, and she became unconscious, with irregular respirations and a pulse of poor quality. The pulse rate at two- or three-minute intervals was as follows: 96, 48, 58, 60, 96, 120. One-fiftieth of a grain of atropine sulphate was given by hypodermic a few minutes after the convulsions began. As her condition, although not good, was not considered to be dangerous, the operation was proceeded with and finished. The patient's condition improved, and she recovered well from the operation, but thirty-five minutes afterward her pulse was 148 and one hour after operation, 120. It was of fair quality but irregular. Her mind was dulled and she remained confused until the following day, when she seemed to be entirely normal mentally, and her pulse ranged between 120 and 112. There were no signs of muscular paralysis at any time, and it is not believed that this operative complication was due to an air embolus. It seems more likely that it was a so-called pleural reflex which was instigated by the manipulations of the intercostal nerves or possibly of the subpleural tissue before induction of complete anesthesia. Hypersusceptibility to the usual amount of novocaine must also be considered.

By June, 1928, the sputum had disappeared and roentgenograms showed that the cavities were much smaller. The patient was then taking ten minutes of walking exercise daily. In March, 1929, the cavities had disappeared, and the patient was walking for two and a half hours a day and, in addition, was occupied for two hours a day with occupational therapy work. In March, 1933, she had no sputum, was working six hours a day as a laboratory technician, and had married. There was slight dyspnea on limited exertion. In May, 1934, she remained well and was working full time in the laboratory. She is classified as apparently cured.

CASE 3.—E. M., a Scandinavian schoolboy of seventeen years, had been in a sanatorium for three and a half years after pulmonary tuberculosis had been diagnosed. At first he had improved and then had become worse. An inadequate pneumothorax had been induced and abandoned in May, 1928. Upon admission to the University Hospital in August, 1928, he had from 30 to 40 gm. of positive sputum daily and slight cough, but no night sweats or dyspnea. Roentgenograms showed extensive fibrocaseous infiltration of the whole left lung with multiple small cavities in the apex and some thickening of the pleura over the whole left lung. In the right lung there was scattered tuberculous infiltration from the apex to the third rib.

The patient was considered a poor risk for a thoracoplasty because of the exudative character of many of the lesions and because he was in decidedly poor general condition. A left phrenic paralysis and intercostal neurectomy of the second to eleventh nerves, inclusive, were chosen in the hope that they would prepare the patient for a thoracoplasty which would probably later be necessary. The phrenic operation was performed on August 24, 1928, and the intercostal neurectomy on September 1, 1928.

By February, 1929, the sputum had entirely disappeared. Roentgenograms showed marked clearing of all the lesions and a change of the remaining ones from the exudative toward the productive type; no cavities were visible. At this time he was taking one-half hour of walking exercise daily. In March, 1933, he reported that he had no sputum, fever or fatigue, and that he had gained 21 pounds since his operation. He was working from six to nine hours a day doing chores but, on account of labor conditions, he had been unable to obtain a regular job. He was seen by us on June 26, 1934. He then had no sputum and was doing light farm work and was able to skate and play baseball without any apparent harm. He is classified as apparently cured.

CASE 4.—M. McG., an Irish school-teacher and book printer, aged twenty-seven years, had had pneumonia in 1915 and in 1917 and several subsequent attacks of

influenza. Pulmonary tuberculosis was diagnosed in April, 1927, when he was confined to bed for several months because of night sweats, fatigue, loss of weight, slight fever, a hacking cough with some nonbloody sputum, and pain in the left lower chest anteriorly. He did not improve, and on July 31, 1927, there was a 15 c.c. hemoptysis; at this time anorexia was pronounced and he suffered from fatigue, weakness, and night sweats.

On February 13, 1928, he was admitted to a sanatorium after having lost 50 pounds. An inadequate left pneumothorax was induced and maintained for only three months. He continued to lose weight and had from 30 to 60 gm. of positive sputum daily. He was strictly confined to bed, and in June, 1928, his temperature was 100.2° and his pulse 88.

Upon admission to the University Hospital on June 22, 1928, he was very sick and emaciated and had marked pallor. His blood pressure was 96/60. Roentgenograms showed dense infiltration throughout the left lung with multilocular cavitation in the upper third and scattered exudative infiltration in the upper half of the right lung.

The patient's downhill course and his poor general condition clearly contraindicated thoracoplasty. In view of the marked success that had attended the combined operation of phrenic paralysis and intercostal neurectomy in our first three patients and in spite of the apparently hopeless condition of this patient, we decided to undertake the operation as a last resort. The phrenic operation was performed on June 22, 1928, and the second to eleventh, inclusive, intercostal nerves were resected on June 29, 1928.

In August, 1928, there were slight general improvement, better appetite and less fever, but the prognosis was still considered to be very unfavorable. In October there was evidence of tuberculous laryngitis.

The roentgenogram of February 26, 1929, showed a diffuse exudative spread of the tuberculosis throughout the upper two-thirds of the right lung and an increase in the size of the cavities and parenchymal infiltration in the left lung. There was also partial obscuration of the pulmonary markings in the lower left lung either by fluid or by parenchymal infiltration.

On March 6, 1929, the patient returned to his home. He was expected to die within a few months, but he lived until March 9, 1930.

CASE 5.—D. S., a salesman, aged twenty-six years, was admitted to the University Hospital on July 10, 1929. Pulmonary tuberculosis had been diagnosed five years before, following an hemoptysis. Pneumothorax had been promptly induced but was abandoned five months later. During the year and a half immediately preceding his admission to the hospital he had been strictly confined to bed. A right phrenic paralysis had been produced six months before admission.

At the time of admission, the patient was very weak, had fever, cough, profuse expectoration, pain in the chest, nervousness, insomnia, and tachycardia, and there had been continued loss of weight during the preceding year. The temperature ranged from 99.4° to 100.2° and the pulse from 100 to 132. Roentgenograms showed extensive tuberculous infiltration throughout the right lung and a cavity that was 10.3 cm. in its greatest diameter; there were scattered productive lesions from the apex to the second rib in the left lung.

In an attempt to check progression of the right-sided lesion and to prepare the patient for a later thoracoplasty, the second to the eleventh, inclusive, intercostal nerves were partially resected on July 12, 1929. The patient's blood pressure fell during the operation but rose the following morning to the preoperative level of 96/73. During the first five postoperative days, he was occasionally cyanosed but not dyspneic; during the next five days there was neither cyanosis nor dyspnea. Sud-

denly, ten days after operation, he became very weak, his blood pressure dropped to 80/64, pulse was 148, and respirations were 36. In spite of stimulation he died within a few hours. Before operation his pulse had ranged between 100 and 132, his respirations between 22 and 30. He had been digitalized. This patient's death from myocardial disease was undoubtedly hastened by the operation, which was performed as a last resort.

CASE 6.—E. C., a woman aged thirty-five years, manager in a department store, was admitted to the University Hospital on July 20, 1929, complaining of cough, sputum, anorexia, night sweats, insomnia, weakness, and loss of 5 pounds in one year. She had had a tonsillectomy eighteen months before and one month later had what was called influenza with cough, sputum, and fever. Later she had four hemoptyses, and pulmonary tuberculosis was then diagnosed. Six months before her admission to the hospital, a diagnosis of tuberculous enteritis had been made on the basis of symptoms and roentgenograms. At the time of her admission she had been confined to bed for fourteen months.

Our first roentgenogram showed mixed productive and exudative tuberculous infiltration throughout the left lung and three small cavities in the upper third of this lung; there were mixed productive and exudative lesions in the mid right lung. The patient's temperature was 99.4°, pulse was from 100 to 110, and the sputum averaged 14 gm. daily and was positive for tubercle bacilli.

Pneumothorax could not be induced, and thoracoplasty was contraindicated because of the exudative lesions in both lungs and the complicating rather active intestinal tuberculosis. On July 22, 1929, the second to tenth, inclusive, left intercostal nerves were partially resected.

During the next three months the patient showed definite clinical improvement with a gain of 5 pounds in weight and marked decrease in the amount of sputum. She then became worse and in December, 1929, had fever to 102° and an increase of sputum to 60 gm. daily. By April, 1930, the left-sided cavities had increased in size, and the right-sided lesions had not progressed. It was felt that a thoracoplasty was needed, and this was performed in April in the face of an obviously poor prognosis. The tuberculosis, however, continued to progress in both lungs, and the patient died on August 12, 1931. With regard to the effects of intercostal neurectomy to the time of thoracoplasty, the patient is classified as unimproved.

CASE 7.—E. A., a twenty-year-old woman, had had pulmonary tuberculosis during the twenty-six months before she was admitted to the University Hospital on December 2, 1930. A left pneumothorax had been unsuccessfully attempted in August, 1930, and at the same time a left phrenic paralysis was produced. At the time of admission to the hospital, the roentgenograms showed a clear right lung and exudative infiltration with probable small cavity in the upper half of the left lung. The patient had been confined to bed since July, 1930. Her temperature was usually somewhat above 99°, her pulse from 96 to 106 and she was raising from 6 to 20 gm. of positive sputum daily.

The patient had had a recent increase in the exudative lesion, and thoracoplasty was, therefore, considered to be an improper operation for her at that time. On December 4, 1930, the posterior portions of the second to eleventh, inclusive, intercostal nerves were resected. Her postoperative convalescence was uneventful, and she returned to her sanatorium on December 19, 1930.

There was gradual improvement in the patient's general condition and in the roentgenologic appearance of the lesions; the daily amount of sputum, however, had increased from 20 to 30 gm., and tubercle bacilli were still present. She became dissatisfied with the sanatorium regimen and left against advice on May 27, 1931.

She died of pulmonary tuberculosis at home on November 4, 1931. Had she remained at the sanatorium she would probably have had a thoracoplasty because her general and local condition had improved sufficiently to justify it.

CASE 8.—R. A., a woman aged thirty-four years, had had pulmonary tuberculosis since May, 1930. In July, 1930, an unsuccessful attempt was made to induce a left pneumothorax, and then a left phrenic paralysis was produced and she was confined strictly to bed.

She was admitted to the University Hospital on December 14, 1931. Roentgenograms showed small scattered areas of infiltration, suggestive of old tuberculous foci, in the right lung from the apex to the second rib and also at the base. Throughout the left lung there were dense exudative infiltration and multiple large cavities in the upper third. The patient's temperature and pulse were approximately normal, and she had from 2 to 10 gm. of positive sputum daily.

We considered this patient to be an unduly poor risk for thoracoplasty because of her relatively poor general condition and particularly because of the exudative character of the extensive lesions. On December 15, 1931, we performed a left intercostal neurectomy of the second to eleventh, inclusive, nerves. She had a severe postoperative reaction of several days' duration, for which we considered the labile exudative lesions responsible.

She was sent back to the sanatorium on January 13, 1932, where she was strictly confined to bed until she was returned to her home with a hopeless prognosis in February, 1933. At home she averaged 100 gm. of positive sputum, was dyspneic, and had fever. She gradually became worse and died on September 6, 1933.

CASE 9.—K. S., a woman, aged twenty-seven years, had had pulmonary tuberculosis for approximately one year and diabetes mellitus for approximately five years before she was admitted to the University Hospital on March 9, 1931.

Upon admission to the hospital she was found to have grave diabetes which required 88 units of insulin a day. Roentgenograms showed extensive bilateral exudative tuberculous infiltration which was localized to a portion of the upper lobe of the right lung and which extended throughout the left lung, in which there were multiple cavities in the lower half. The patient's temperature was normal, pulse from 90 to 100, and she had from 4 to 8 grams of positive sputum daily.

An unsuccessful attempt was made to induce a left pneumothorax. The left phrenic nerve was paralyzed on March 19, 1931. This operation was followed by some diminution in sputum, but it remained positive for tubercle bacilli. The grave diabetes and the bilateral exudative tuberculous lesions clearly contraindicated thoracoplasty. On June 6, 1931, the second to eleventh, inclusive, left intercostal nerves were paralyzed. During the next two weeks, the patient seemed to be definitely improved, her temperature remained normal, and her pulse ranged between 90 and 110. The sputum almost completely disappeared, but in August, 1931, it was still positive. Roentgenograms showed increase in the size of the cavities in the left lung. Although the diabetes was under control, she was still considered to be too poor a risk for thoracoplasty. Monthly roentgenograms showed a gradual progression of the bilateral exudative lesions, and the diabetes became increasingly difficult to control. In September, 1932, there were increased fever and pleural pain. The patient continued to become gradually worse, and she died on February 21, 1933. Terminally she had the symptoms of tuberculous meningitis.

CASE 10.—H. J., a twenty-one-year-old farmer, had an influenzal type of onset of pulmonary tuberculosis one year before he was admitted to the University Hospital on August 11, 1931. He complained of fever, weakness, and the expectoration of from 60 to 70 gm. of sputum daily, which was found to be positive for tubercle

bacilli. Diabetes mellitus and tuberculous laryngitis were found to be present. Roentgenograms showed no evidence of disease in the right lung; there were patchy dense exudative tuberculous infiltration in the left lung from the apex to the fifth rib and a small cavity in the second intercostal space.

Pneumothorax treatment was promptly begun, but it failed because of extensive pleural adhesions. The left phrenic nerve was interrupted on September 1, 1931. Ten weeks later the patient's temperature was somewhat more than 99°, the pulse was from 80 to 100, and the sputum from 30 to 80 gm. daily and positive for tubercle bacilli. Because of the complicating diabetes and the exudative character of the left-sided lesion, a thoracoplasty was believed to be contraindicated at the time. Left intercostal neurectomy of the second to eleventh, inclusive, nerves was performed on November 11, 1931. Following this operation the sputum was halved in amount, and the temperature remained consistently below 99°. On April 23, 1932, he was transferred to a sanatorium.

In May, 1932, the temperature was normal, the pulse varied between 72 and 90; the sputum was 25 gm. in amount daily and positive for tubercle bacilli. Roentgenograms showed definite clearing of the left-sided lesion but the cavity was still present. The patient was then considered a suitable risk for thoracoplasty, which was performed in four stages during the early summer of 1932. His operative convalescence was uneventful.

In February, 1934, he reported that he hunted and fished, had gained 34 pounds in weight since the thoracoplasty operation and that he would have been working if he could have found a job. The sputum was negative when examined in January, 1934. It seems obvious to us that the intercostal neurectomy operation was chiefly responsible for turning this patient's downward course upward, and for making him a suitable risk for thoracoplasty, which apparently healed the tuberculous lesions.

CASE 11.—K. K., a twenty-four-year-old graduate nurse, had had symptoms of active pulmonary tuberculosis for six months before she was admitted to the University Hospital on November 18, 1931. She had pain in her chest, fatigue, and occasional fever to 101°. Her pulse ranged between 90 and 100, and the sputum amount varied between 2 and 20 grams daily and contained tubercle bacilli. Roentgenograms showed some "peritruncal infiltration" in the left lung and, in the right lung, a rather dense exudative infiltration from the apex to the third rib with multiple small cavities in this region.

A right-sided pneumothorax was begun on November 25, 1931, but was soon abandoned because of extensive pleural adhesions. A right phrenic paralysis was produced on November 28, 1931. The larynx was believed to have a slight tuberculous infiltration. The sputum increased markedly in amount and remained positive. The unstable exudative lesions contraindicated thoracoplasty at the time. The second to eleventh, inclusive, intercostal nerves were interrupted posteriorly on April 21, 1932. During the next two months the patient gradually improved but the cavernous lesions persisted.

The patient was transferred to a sanatorium in June, 1932, where she continued bed rest. In March, 1933, she was still a bed patient except that she was permitted to get up for one meal a day. She then was raising from 1 to 2 gm. of clear sputum daily which had been negative for tubercle bacilli since August, 1932.

In May, 1934, the temperature was normal, the pulse ranged between 80 and 96, and the sputum was occasionally positive for tubercle bacilli. The sputum was frequently slightly blood streaked. The roentgenograms showed a probable honeycombing in the right infraclavicular region. In view of this and the occasional positive sputum a five-rib thoracoplasty in two stages was performed during the summer

of 1934. Several weeks after operation no cavity could be visualized in the roentgenograms and the sputum had become negative. We believe that the intercostal neurectomy was largely responsible for this patient's progressive improvement, which made a thoracoplasty possible without undue risk.

CASE 12.—J. McI., a twenty-three-year-old woman, had had pulmonary tuberculosis for seven years when she was admitted to the University Hospital on August 5, 1932. Upon admission she had no complaints except slight cough and the occasional expectoration of from 1 to 4 gm. of positive sputum. The temperature was normal, the pulse rate between 76 and 84, and her general condition was excellent. Roentgenograms showed scattered old foci throughout the right lung and, in the upper third of the left lung, dense infiltration, pleural reaction, and possible multiple small cavities (Fig. 1).

Left pneumothorax had been begun in June, 1930, but was lost a year later through obliterative pleuritis. The left phrenic nerve had been paralyzed on August 6, 1930. An ulcerative tuberculous laryngitis had healed after a year of vocal silence.

We felt that this patient needed additional assistance in the healing of the left-sided lesion because of its chronic activity and the persistence of positive sputum. We believed that intercostal neurectomy might be sufficient and that, in view of the small size of the probably present pulmonary cavities, this operation would be preferable to the more radical operation of thoracoplasty. Intercostal neurectomy of the second to ninth, inclusive, nerves was performed on August 15, 1932, and shortly thereafter the patient was returned to the sanatorium.

By February, 1933, the patient was out of bed four hours a day, was having three meals a day in the dining room, and had no sputum (Fig. 2). She was dyspneic only if she was out of bed for an unusually long time. In May, 1934, the temperature, pulse and respiration rates were normal, and she continued to have no sputum. Roentgenograms on May 10, 1934, showed progressive fibrosis of the lesions. She was then doing "occupational therapy work." She was discharged from the sanatorium on June 2, 1934, as an arrested case.

CASE 13.—C. B., a twenty-eight-year-old farmer, began to have active pulmonary tuberculosis probably four years before his admission to the University Hospital on July 15, 1932. In February, 1932, he had had an hemoptysis of 3 ounces but continued to work in spite of increasingly severe symptoms. Upon admission he complained of dyspnea and fatigue. His temperature was 101°, his pulse 100 and he was raising a maximum of 20 grams of positive sputum daily. Roentgenograms showed tuberculous infiltration in the right lung from the apex to the fourth rib and in the left lung a dense infiltration from the apex to the sixth rib with multiple large cavities in the upper half of the lung.

Pneumothorax was attempted on the left side but failed because of adhesions. Thoracoplasty was clearly contraindicated because of the activity of the rather extensive lesions in the better, or right, lung. On September 17, 1932, the left phrenic nerve was paralyzed, and the scalene muscles were resected. On September 29, 1932, the second to the tenth, inclusive, left intercostal nerves were paralyzed.

Not long after the intercostal nerve operation the sputum decreased to 6 grams daily and became constantly negative. The temperature remained normal; whereas before operation it was usually between 99° and 100°. The pulse ranged between 80 and 100. The patient was transferred to a sanatorium.

In May, 1934, the temperature was normal and the pulse ranged between 76 and 88. There were 5 gm. of negative sputum daily. Roentgenograms showed marked clearing of the right-sided lesion and clearing and organization of the left-sided

lesion; no cavity was visible. The patient is still under treatment in a sanatorium and he is now beginning to get out of bed and to take his own baths.

CASE 14.—E. L., a woman, aged twenty-one years, had had pulmonary tuberculosis for four and one-half years before she was admitted to the University Hospital on January 20, 1932. She had had a left-sided therapeutic pneumothorax for twenty-two months in 1928 and 1929, but the pneumothorax had been lost. A left phrenic nerve paralysis had been produced in February, 1931.

For several weeks before admission her temperature had occasionally reached 100°, the pulse ranged between 104 and 128, and she was raising 140 grams of mucopurulent sputum daily which was positive for tubercle bacilli. There was roentgenologic evidence of intestinal tuberculosis. Roentgenograms showed no lesion in the right lung; in the left lung there was a dense exudative infiltration from the apex to the fourth rib with three moderately large cavities in the upper half of the lung (Fig. 3).

Although the roentgenograms seemed to present a compelling indication for thoracoplasty, we considered this operation to be contraindicated because of the persistently rapid pulse and the exudative character of the tuberculous lesion. It was hoped that multiple intercostal neurectomy would prepare the patient for a later thoracoplasty. The intercostal neurectomy operation of the second to eleventh, inclusive, nerves was performed on January 25, 1932.

Shortly after operation the patient was returned to a sanatorium to continue strict bed rest. In April, 1932, the temperature was normal except for an occasional 99°, the pulse ranged between 78 and 100, the sputum between 30 and 180 grams daily; tubercle bacilli were still present. Roentgenograms showed considerable clearing and organization of the lesions throughout the left lung; two of the three cavities had increased in size and the third had decreased (Fig. 4).

In April, 1932, the patient was considered to have improved sufficiently so that thoracoplasty might be undertaken without undue risk. A staged, eleven-rib thoracoplasty was performed in April and May, 1932. In February, 1934, the patient reported that she was doing her own housework for three or four hours daily. The sputum was negative and she felt well.

We believe that intercostal neurectomy initiated the improvement in this patient that made the necessary thoracoplasty possible.

CASE 15.—I. C., a woman, aged twenty three years, had had pulmonary tuberculosis since October, 1930. The right phrenic nerve had been paralyzed in November, 1932. The patient was admitted to the University Hospital on June 21, 1932. She was in poor general condition, had a pulse that ranged between 80 and 120; the temperature was frequently higher than 99°; the vital capacity was 1,200 c.c. and she had approximately 40 gm. of sputum daily, which was positive for tubercle bacilli. Roentgenograms showed scattered tuberculous foci in the upper two-thirds of the right lung and an elevated right diaphragm; there was in the upper third of the left lung a dense exudative infiltration which contained a cavity 5×3 cm.

We felt that the patient's general condition, the exudative character of the tuberculous lesion in the left lung, and the presence of considerable tuberculous infiltration in the right lung precluded immediate thoracoplasty. In the hope that the patient might be prepared for a thoracoplasty by the operation of intercostal neurectomy, the second to the eighth, inclusive, intercostal nerves were resected on June 23, 1933. The patient was returned to the sanatorium on July 6, 1933, to continue bed rest.

In November, 1933, roentgenograms showed marked clearing and organization of the left-sided lesion but no change in the size of the cavity; the right-sided lesion also showed clearing and organization. The vital capacity was 1,200 c.c. We felt

that the lesions in the better lung were too extensive and the vital capacity still too low to justify a thoracoplasty at this time. The left phrenic nerve was, however, temporarily paralyzed, and the patient was placed on a Bradford frame to reduce the amount of her physical activities.

In February, 1934, the roentgenograms showed a new 2 cm. cavity in the left lung but no other appreciable change. In May, 1934, the patient was still on the Bradford frame; the pulse ranged between 80 and 112; the temperature was occasionally 99.2°, and the sputum varied between 8 and 15 gm. daily and had remained positive for tubercle bacilli upon occasional examination. The patient was making slow improvement, but it is questionable whether she will become a suitable risk for thoracoplasty.

CASE 16.—E. M., a woman, aged twenty-eight years, had had pulmonary tuberculosis since May, 1931. In May, 1932, she had a normal parturition and continued treatment for tuberculosis. A right-sided pneumothorax had been undertaken but was abandoned as unsuccessful. The right phrenic nerve had been paralyzed in November, 1931.

The patient was admitted to the University Hospital on May 24, 1933. She was in good general condition, had a normal temperature, and a pulse that ranged between 80 and 90. The sputum was mucopurulent, from 4 to 5 gm. daily in amount, and positive for tubercle bacilli. Roentgenograms showed a moderately dense exudative infiltration in the upper half of the right lung and a small area of infiltration in the middle third of the left lung. Comparison of these roentgenograms with previous ones showed that there had recently been an extension of the right-sided lesion. For this reason we felt that intercostal neurectomy was a more conservative measure than thoracoplasty.

On May 29, 1933, the second to the ninth, inclusive, right intercostal nerves were paralyzed, and on June 15, 1933, the three scalene muscles on the right side were partially resected. We performed the intercostal neurectomy in the expectation that it would be sufficient to bring about healing of the lesion; we did not expect that thoracoplasty would later be necessary.

The patient returned to the sanatorium, and in May, 1934, the temperature was normal, with an occasional rise to 99°; the pulse range was in the 80's, and she had from 3 to 10 gm. of sputum daily which had been negative for tubercle bacilli since the intercostal neurectomy operation had been performed.

Roentgenograms on February 7, 1934, showed marked clearing and organization of the right-sided lesions and some organization of the left-sided lesions. Roentgenograms on August 2, 1934, showed only a few fibrotic lesions in the right lung and a few stringy scars in the left lung. Sputum had been negative by concentration test and culture since the time of the intercostal neurectomy operation, except for a single positive examination on February 12, 1934. In November, 1934, there were a slight elevation of temperature, increased cough, positive sputum, and the roentgenograms showed progressive absorption and fibrosis of the right-sided lesions which, however, contained multiple small cavities; the lesions in the left lung were few and fibrotic. A right-sided partial thoracoplasty was clearly indicated in view of the cavitation and positive sputum. Since the patient's general condition was excellent, the operation was recently begun, the first stage having been performed in January, 1935.

CASE 17.—M. L., a young woman, aged nineteen years, developed tuberculosis in February, 1932, and became a bed patient in July, 1932. Before her admission to the University Hospital on June 8, 1933, twelve unsuccessful attempts to induce pneumothorax had been made. A left phrenic paralysis had been performed on October 31, 1932.

Upon admission the patient's temperature was 101°; the pulse ranged between 80 and 90; and the sputum ranged between 50 and 100 gm. daily which was positive for tubercle bacilli. Roentgenograms showed a dense exudative tuberculous infiltration throughout the left lung, which was more marked in the upper third where there was a cavity 2 cm. in diameter; in the middle of the right lung there was a small tuberculous infiltration.

We believed that the lesions were too active to permit thoracoplasty. The second to the tenth, inclusive, left intercostal nerves were interrupted in two stages in June, 1933, and early in July the three left scalene muscles were partly resected. The patient returned to the sanatorium.

Roentgenograms on October 18, 1933, showed a considerable pleuritic reaction throughout the left chest. Roentgenograms on January, 1934, showed marked clearing of the pleuritic reaction but no change in the right-sided lesion. In May, 1934, the patient was still in bed; the pulse ranged from 70 to 90; and the temperature was never more than 98.8°. Sputum amounted to from 2 to 6 gm. daily; it was positive once in March but negative twice in April.

We consider that this patient has been improved by the intercostal neurectomy and that further improvement may be expected.

CASE 18.—M. R., a woman, aged thirty-eight years, had had pulmonary tuberculosis since February, 1932, and she entered a sanatorium in May, 1932. When she was admitted to the University Hospital on June 19, 1933, the temperature ranged between 99° and 100°; and the pulse rate ranged between 100 and 120. Sputum varied between 15 and 35 gm. daily and contained tubercle bacilli. A right-sided pneumothorax was initiated in May, 1932, and the right phrenic nerve was interrupted. The pneumothorax was abandoned in December, 1932, because of insufficient pulmonary collapse and persisting pleural effusion. Roentgenograms on admission showed a dense exudative infiltration throughout the right lung with a 3 cm. cavity below the clavicle and a marked pleuritic reaction; there was a moderately dense exudative infiltration at the level of the second and third anterior intercostal spaces in the left lung.

A right-sided thoracoplasty was contraindicated because of the extensive exudative lesions. Right intercostal neurectomy of nerves two to ten, inclusive, was performed in two stages in June and July, 1933, and between these stages the three right scalene muscles were partially resected. The patient was returned to the sanatorium.

The roentgenograms in May, 1934, showed some clearing and fibrous organization of the lesions in both lungs, but the size of the cavity in the right lung remained unchanged. In May, 1934, the pulse was usually about 80, but occasionally rose to 110; the temperature was normal with a rare elevation to 99°. The amount of sputum was from 15 to 20 gm. daily; the last tubercle bacilli were found in January, 1934. A small tuberculous empyema was present (pneumothorax had been abandoned in December, 1932, because of persisting pleural fluid). In August, 1934, a right-sided thoracoplasty was begun; two of the three intended stages have now been performed and the patient has reacted well to them.

CASE 19.—E. B., a woman, aged thirty-one years, had an hemoptysis but no other symptoms of active pulmonary tuberculosis in November, 1931. In June, 1932, during her first trimester of pregnancy, she began to have fatigue; and in January, 1933, following delivery, a diagnosis of pulmonary tuberculosis was made from positive sputum and roentgenograms. A right-sided pneumothorax was begun in April, 1933, but was soon abandoned because of extensive pleural adhesions. During the five months prior to her admission to the University Hospital on September 11, 1933, the patient had had several exacerbations of fever to 100° and once to 102°.

Her pulse ranged from 80 to 120, and the sputum amounted to from 20 to 25 gm. daily and was positive for tubercle bacilli. The patient had failed to gain in weight. A right phrenic nerve paralysis was produced on May 2, 1933.

The roentgenograms in September, 1933, showed a soft infiltration throughout the right lung, with subtotal obscuration of the pulmonary markings below the sixth posterior intercostal space; comparison of these roentgenograms with previous ones showed that the lesion had progressed. The films made in September showed a minimal tuberculous infiltration at the left apex.

We felt that thoracoplasty was definitely contraindicated in view of the extensive and advancing lesions in the right lung. We hoped that intercostal neurectomy would check the advance of the lesion, and during the last of September, 1933, the second to the eleventh intercostal nerves were paralyzed in two stages.

Ten days after operation the temperature which before operation had daily reached from 99.5° to 101.5°, fell to a daily maximum of from 99° to 99.5° and remained at that level until the patient was returned to the sanatorium twenty-one days after operation.

In May, 1934, the patient had improved so much from both the clinical and the roentgenologic points of view that she was considered a reasonable risk for a staged thoracoplasty. We were, however, suspicious that the persisting obscuration of the right lower lung in the roentgenogram might be an expression of a partially obstructive tuberculous bronchitis of the right lower lobe bronchus, and therefore we bronchoscoped the patient and found in the right lower stem bronchus granulations and ulcerations which appeared to be characteristic of ulcerative stenotic tuberculous bronchitis. Since we feel at present that such a lesion presents an ultimately hopeless prognosis and that collapse therapy in such a patient is more likely to do harm than good, we did not perform a thoracoplasty in this patient.

CASE 20.—A. B., a thirty-two-year-old woman, had first symptoms of pulmonary tuberculosis in January, 1929. From then until her admission to the University Hospital in July, 1932, she had frequent remissions and exacerbations of the symptoms of active tuberculosis. At the time of admission she had fever, fatigue, night sweats, cough, and expectoration. The sputum was positive for tubercle bacilli, and she had ulcerative tuberculous laryngitis. Roentgenograms showed extensive bilateral pulmonary tuberculosis with probable cavitation in the right apex. An unsuccessful attempt to induce pneumothorax on the right side was made in October, 1932.

Although she remained in bed, there was scarcely any improvement until after January 24, 1933, when the right phrenic nerve was paralyzed. The laryngeal lesions improved somewhat, and the sputum, which was 50 gm. daily, was occasionally negative. Her general condition and the roentgenographic appearance of the lesion, however, had not improved. In October, 1933, the roentgenograms showed a dense exudative infiltration throughout the right lung with a cavity in the first intercostal space, and there was scattered infiltration in the upper half of the left lung.

We felt that a right-sided thoracoplasty would be too dangerous at this time because of the considerable activity of the left-sided lesion. On October 20, 1933, intercostal neurectomy of the second to tenth, inclusive, intercostal nerves was performed.

In May, 1934, the amount of sputum had become reduced to from 5 to 20 gm. daily and was negative for tubercle bacilli. Temperature and pulse were normal. Roentgenograms showed definite organization and clearing of the right-sided lesion and decrease in the size of the cavity; the left-sided lesion also presented clear evidence of fibrous organization. On March 6, 1934, a pneumoperitoneum was induced for intestinal tuberculosis. The patient is still confined to bed.

This patient's general condition and pulmonary condition have been definitely improved since the time of the intercostal neurectomy operation. With the right-sided pulmonary cavity, which has decreased in size since operation, becoming progressively smaller, decision as to thoracoplasty will be deferred, but if the cavity fails to close a thoracoplasty will be performed.

CONCLUSIONS

1. Intercostal neurectomy is indispensable for occasional cases of pulmonary tuberculosis in which pneumothorax has failed because of pleural adhesions and in which phrenic paralysis, together with prolonged bed rest, has been found to be inadequate and yet in which persisting or progressive symptoms demand additional treatment. This conclusion is based upon a careful review of our patients who have been operated upon during the past seven years.

2. The only collapse therapy measures that could be expected to control the lesions in such patients are thoracoplasty and intercostal neurectomy. Thoracoplasty was definitely contraindicated by the unstable predominantly exudative character of bilateral or unilateral lesions or for other reasons in 19 of our 20 patients at the time that intercostal neurectomy was performed.

3. In six of our patients we believed that intercostal neurectomy would be sufficient to bring about healing of the lesions; in five of these patients thoracoplasty would have been contraindicated at the time because of the unstable condition of predominantly exudative unilateral or bilateral lesions. Two of these six patients are apparently cured, one is arrested, and three are improved. One of the improved patients now has negative sputum and two later required a thoracoplasty. In one of these two the cavity is closed and the sputum negative; the thoracoplasty in the other patient has just been begun.

4. Twelve of our 20 patients had cavities of such size that thoracoplasty was obviously necessary to close them, but this operation was clearly contraindicated at the time because of the poor general condition of the patients and, in most of them, the presence of unstable exudative unilateral or bilateral lesions. In all 12 patients the clinical picture indicated a decidedly poor prognosis. Intercostal neurectomy was performed in the expectation that the patients or their lesions, or both, would be made suitable risks for thoracoplasty.

Two patients in this group had moderately advanced tuberculosis, and ten had far advanced tuberculosis, according to the classification of the National Tuberculosis Association. Following intercostal neurectomy one patient was apparently cured, seven were improved, one was not improved, and three died from eleven to twenty-one months postoperatively. Of the seven improved patients, one now has fibrotic lesions and negative sputum and is beginning therapeutic exercise; three have had thoracoplasty, two of them now having negative sputum

and one having only recently been operated upon; one patient has been diagnosed as having a complicating tracheobronchial tuberculosis that contraindicates a thoracoplasty, which otherwise would now be feasible; two improved patients may still become suitable risks for thoracoplasty.

5. Encouraged by several surprisingly successful results in gravely ill patients, we performed intercostal neurectomy upon two patients who were almost hopelessly ill in a desperate effort to save them. Both died and we now advise against the use of the operation for such cases.

6. Intercostal neurectomy should not be used unless bed rest and pneumothorax have been undertaken and failed, and if phrenic paralysis alone might suffice. Under these conditions certain patients with unstable predominantly exudative unilateral or bilateral lesions, which contraindicate thoracoplasty, may recover entirely after intercostal neurectomy, and other patients with large cavities may improve sufficiently to permit the reasonably safe performance of thoracoplasty.

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CHEST IMMOBILIZATION IN PULMONARY TUBERCULOSIS*

An Experimental Study

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INTRODUCTION

THERE has been little controlled experimental work to determine the comparative value of surgical modes of treating pulmonary tuberculosis. It is difficult to produce a good localization of the organisms in the lungs of most laboratory animals; by the time the disease is extensive they usually die. Moreover, various thoracic operative procedures entail a considerable mortality in animals, so the experiment becomes costly.

We have tried to ascertain the effect of unilateral phrenicectomy upon tuberculosis in the guinea pig. With this we compared multiple intercostal neurectomy, a little known procedure; and also immobilization of the costal wall by splinting the ribs together with tapes and metal bands. Each of these procedures was carried out upon the right sides of the various animals. Some time after recovering from the operation, they were inoculated subcutaneously in the right groin with a virulent strain of human tubercle bacilli. We selected this method of inoculation because, although it may give slow or rapid spread in different animals,[31] on the whole it causes good bilateral pulmonary lesions about two months after injection.[40] Calmette[10] and Cooper and Lurie[14] have shown that the result is the same as after intravenous or intracardiac injection; fairly even spread to the two lungs.

Our belief was that the operated side, being in a condition of partial rest, should be able better to combat the infection and, therefore, should show fewer tuberculous lesions both to x-ray and to gross examination at necropsy. X-ray films were made eight weeks after inoculation, and necropsy was carried out approximately one month later. The question may be raised that the bacilli should tend to be deposited more in the motionless lung, since the blood flow will be slower through it; but L. U. Gardner[21] has demonstrated that miliary tuberculosis in man does not localize in a collapsed lung.

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Based upon a thesis presented by the senior author to the faculty of the Yale University, School of Medicine, in partial fulfillment of the requirements for the degree of Doctor of Medicine.

Received for publication, November 26, 1934.

All the animals included in this report were allowed to die of their disease. Controls were used to make certain that this method of injection did give an equal distribution of lesions in the two lungs.

PHRENICECTOMY

Section of the phrenic nerve was proposed by Stuertz[38] of Cologne in 1911. Two years later Schepelmann[34, 35] tried its effect on dogs, noting the rise of the diaphragm and finding no disturbance of heart or respiration. At about the same time, Sauerbruch[33] began using it upon human beings, apparently with some improvement. Not until the last few years has the operation come into popular use in this country.

W. Carl[11, 12] of Königsberg in 1914 made a few experiments upon rabbits, inoculating them with tuberculosis first and later doing a

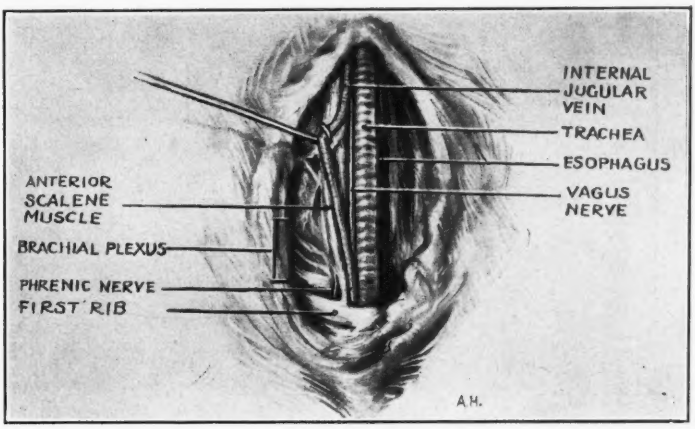

Fig. 1.—Exposure for phrenicectomy in the guinea pig.

phrenicectomy. Necropsy revealed a "depression of the chest" on the operated side and a shrunken lung. He states further that there was less disease on that side, but gives no figures. No others, so far as we have been able to learn, have attempted to discover the effect of phrenicectomy upon the tuberculous lungs of animals. Schlaepfer,[36] Dünner and Mecklenburg,[16, 17] Balice,[5] and Lemon[27] have studied the procedure itself on dogs; and Schnippenkötter[37] has worked with cats. All these investigators are agreed that there is retraction of the lung and frequently atrophy of the hemidiaphragm.

We used ether anesthesia and aseptic technic in all our operations. The phrenic nerve is difficult to locate in the guinea pig; since it is quite small and apparently arises chiefly from the fifth and sixth cervical roots. A midline incision is satisfactory. The platysma myoides is then divided and the deep fascia cut in the line of incision. Dissection here

is rendered difficult by several branches of the thyroid axis and communications between the external and internal jugular veins. The phrenic nerve arises quite low down in the neck, a few millimeters lateral and posterior to the vagus which is easily found. Reference to Fig. 1 will show how soon the nerve passes posterior to the first rib and subclavian artery into the thorax, there being no clavicle in these animals. This nerve may be distinguished from other small nerves in the immediate neighborhood if one passes a probe under it and elevates it slightly; it is then seen to pass into the thorax rather than to one of the neck or shoulder muscles. Avulsion of the nerve with a mosquito clamp removes about 2 cm. before the nerve breaks.

Right phrenicectomy as described above was performed upon several guinea pigs. After recovering from the operation the animals were fluoroscoped, when it was found that the right hemidiaphragm

Fig. 2. Fig. 3.

Fig. 2.—X-ray film of guinea pig No. 18. Right phrenicectomy April 28. Inoculated July 27. X-ray picture taken September 18 shows distinctly more tuberculosis on the left.

Fig. 3.—X-ray picture of guinea pig No. 56. Right phrenicectomy April 8. Inoculated July 27. X-ray picture taken September 19 shows right lower lung clear, with an acute pneumonic process in the left lung.

was motionless. Three months after operation they were inoculated subcutaneously in the right groin with human tubercle bacilli. The animals soon presented signs of tuberculosis—enlarged lymph nodes; coarse, ruffled hair; loss of weight. Eight weeks after inoculation roentgenograms were taken to determine the amount of tuberculosis. To obtain these films the animals can be made to cease respiration for two or three seconds by holding the mouth shut and quickly occluding the nostrils. About ten to twelve weeks after inoculation, as each guinea pig died, its lungs were examined; the relative distribution of tuberculosis in the two lungs was determined roughly on the external surfaces and on gross cut sections.

Only six animals had sufficient pulmonary tuberculosis to warrant inclusion in this series. To x-ray examination, two of these (Figs. 2 and 3) showed a preponderance of lesions on the left or unoperated side; the remaining four had equal distribution. At necropsy, one month later than the x-ray examination, three showed more lesions on the left and three had equal distribution. In no case was there more disease on the right side, which had been in a state of rest.

MULTIPLE INTERCOSTAL NEURECTOMY

Sir Charlton Briscoe[9] in a series of careful observations has proved that expansion of the thoracic cage is a considerable factor in respiration. This is accomplished by an elevation of the anterior portion of each rib; in this way its obliquity becomes less, and the transverse diameter of the chest from vertebral column to sternum increases. Moreover, the lengths of the first seven ribs increase from above downward; when the ribs are elevated and the seventh rib occupies the position previously occupied by the sixth, and so on, there is also an increase in the lateral diameter of the chest. The inspiratory movements of the bony thorax are accomplished in quiet breathing chiefly by the external intercostals.[23, 24] Normal expiration is essentially passive. A mooted point has been the action of the internal intercostals and the subcostals. Martin and Hartwell,[28] however, some time ago proved quite definitely that these muscles contract only in expiration.

It is common knowledge that patients with anterior poliomyelitis, who have bilateral paralysis of the intercostal muscles, but with an efficient diaphragm, suffer a marked loss in vital capacity—these are the cases most successfully treated in a Drinker respirator. Mickey,[29] too, has found a persistent, partial and variable limitation of thoracic movements following unilateral intercostal neurectomy. Because of these facts, we decided to determine the effects of the procedure on experimental animals.

In 1914 Friedrich[19, 20] performed both intercostal neurectomy and phrenicectomy upon a far-advanced case of unilateral tuberculosis, obtaining a favorable result. He also combined section of the intercostal nerves with partial thoracoplasty, in another case, with a good outcome. In view of this success Warstät,[39] his assistant, tried intercostal neurectomy alone upon some rabbits. Some were injected with tuberculosis before and some after operation; in the great majority of those that lived long enough, fewer and smaller tubercles were found on the operated side. He felt that the procedure is fitted for therapeutic use on man, but believed that further experimental work should be done with the partial operation. Bonomo[7] in 1927 reported having resected all the intercostal nerves in a case of pulmonary tuberculosis, but does not give the result. John Alexander has tried the procedure on at least six patients and is well satisfied;[1, 2, 3] he recommends it par-

ticularly in cases when thoracoplasty is contraindicated because the patient is too weak or in selected cases of mild cardiocirculatory failure. This operation is, of course, much less shocking to the patient than thoracoplasty.

Cetrángolo[13] combined phrenicectomy with multiple intercostal neurectomy on the same side; at the time of his report it was too early to judge the result, but an exhausting radiologic study revealed complete lack of motion on the operated side.

The intercostal nerves are fairly easily found, running below their respective ribs between the external and the internal intercostal muscles. Their situation in man has been described in detail by Johnston,[25] and in animals by Delmas.[15] The lowest nerves are located about halfway between the ribs; as one proceeds up the thorax, one finds the nerve more closely beneath its respective rib. Using ether

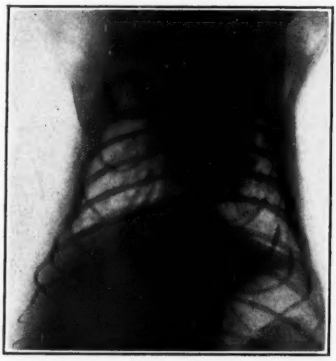

Fig. 4.—X-ray picture of guinea pig No. 9. Right intercostal neurectomy, fourth to twelfth nerves inclusive. X-ray picture taken seven weeks after inoculation shows right lower lung field well defined, while there are many shadows in the left lower lung.

anesthesia and aseptic technic the skin was incised along the right border of the erector spinae muscle group. In this way each nerve may be sectioned near its origin and about 2 cm. avulsed. At this point, of course, the internal intercostal muscle is represented only by a thin fascia; so care must be taken not to injure the pleura. We sectioned the fourth to twelfth right-sided nerves inclusive, so as to determine the effects of partial operations. After the animals had recovered from the operation, fluoroscopy disclosed widening and relaxation of the intercostal spaces on the right in all cases.

These animals were inoculated as described above; x-ray films were made eight weeks later; necropsy was carried out when the animals died, usually about twelve weeks after infection. Only seven animals died with sufficient tuberculous lesions to be included in this report; of these, two died before x-ray examinations were made. Of the five

which were x-rayed, one guinea pig showed more disease on the right or operated side, one more on the left (see Fig. 4), and the remaining three equal distribution. At necropsy the same animal still had more extensive lesions on the right, but four had more disease on the left, and two had equal distribution. There was found definite fibrosis of the intercostal muscles, the nerves of which had been removed.

UNILATERAL RIB IMMOBILIZATION

Following thoracoplasty there is inevitably considerable deformity of the chest. We tried the operation of rib fixation by internal splints as a possible substitute, hoping that the ribs not only could be immobilized but also could be drawn more closely together, thus tending to diminish the size of that part of the chest.

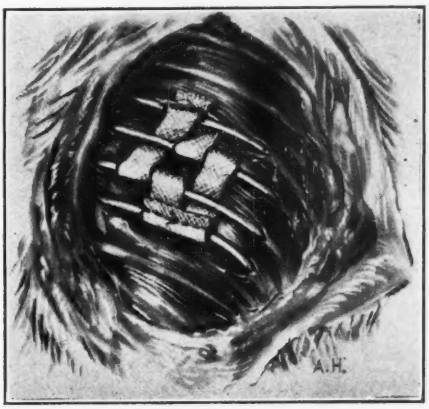

Fig. 5.—Method of rib splinting with linen tape.

It is common practice to restrict motion of an apex with a sandbag. Porges[30] and Golden[22] have bandaged the hemithorax with adhesive tape, preventing any movement; their results were most gratifying, both in decreasing the symptoms and in showing evidence of healing in roentgenograms. Kochs[26] bandaged the hemithorax in normal adults and found a decrease in vital capacity as great as that produced by either artificial pneumothorax or phrenicectomy, 300 to 400 c.c.; in one normal subject who was bandaged thus for ten days there was a lowering of vital capacity by 900 c.c. Rib fixation by internal splints should prove more permanent and effectual than by external bandaging. Mickey[29] found it promising in an acute experiment upon a dog.

At first we tried using soft metal bands 2 mm. wide to bind the ribs together, but there was so much difficulty in applying them without

fracturing the small ribs of the guinea pig that we turned to the use of a linen tape nearly 1 cm. wide. Our incision was made in the mid-axillary line and the latissimus dorsi and serratus magnus were sectioned in the line of incision. After the ribs were exposed, the periosteum was incised and elevated all the way around the rib for a distance somewhat greater than the width of the tape. This was sutured

Fig. 6. Fig. 7. Fig. 8.

Fig. 6.—X-ray picture of guinea pig No. 4. Lowest four ribs on right splinted April 7. X-ray picture taken seven weeks after inoculation shows distinctly more tuberculosis on the left.

Fig. 7.—X-ray picture of guinea pig No. 15. Splinted lower six ribs on right, April 24. X-ray picture taken seven weeks after inoculation shows much more tuberculosis on the left.

Fig. 8.—X-ray picture of guinea pig No 57. Wired lowest seven ribs on right, February 7. X-ray picture taken seven weeks after inoculation shows right lower lung field clear, while the left lung has the diffuse mottling of tuberculosis.

around the thirteenth rib and the remainder of the tape divided lengthwise. Each longitudinal half was wound around the twelfth rib once, but in opposite directions, and was continued in like manner upward (see Fig. 5). Ordinarily, six or seven ribs were all that we were able to operate on in one stage. As the tape was being applied, the ribs were drawn more closely together to decrease the size of the hemithorax.

The postoperative course was always stormy, and we lost many animals. Although strict asepsis was observed and the wound was well closed, it seemed as if nothing could prevent infection from setting in. The presence of the tape caused the animal to bite at its wound, keeping it open. Most of the wounds did not heal for two or three months. Therefore, we decided not to proceed with further stages; but to discover the effects of partial operations. The animals were inoculated from three to five months after operation, and roentgen and postmortem examinations were made as in the preceding experiments.

Only six guinea pigs survived these procedures and developed pulmonary tuberculosis. Of these, three showed more tuberculosis on the unoperated side to x-ray examination, the remainder having equal distribution in the two lungs. However, at necropsy only one had a left-sided predominance, the rest having equal distribution (Figs. 6, 7, 8).

THE CONTROLS

Six controls, never operated upon, were inoculated subcutaneously with tubercle bacilli in the same way and at the same time as the other animals. Of these, all showed equal distribution of pulmonary lesions to x-ray examination; at necropsy four had equal distribution and two had a right-sided predominance, the side upon which we had operated in the other animals. Despite our initial assumption to the contrary, it may be that inoculation of the organisms into the right groin exerted an unfavorable influence on our experiments.

SUMMARY

Experimental studies of three procedures are presented: phrenicectomy, multiple intercostal neurectomy, and rib splinting by internal bandaging. The operations were performed upon the right sides of guinea pigs, and the animals were inoculated later with tubercle bacilli. There was a control group of six unoperated animals. X-ray and postmortem examinations were used to determine the effect of operation. Table I shows the results.

TABLE I

	LEFT (UNOPERATED) PREPONDERANCE	RIGHT (OPERATED) PREPONDERANCE	EQUAL DISTRIBUTION	TOTAL
X-ray examination				
Phrenicectomy	2	0	4	6
Intercostal neurectomy	1	1	5	7
Rib fixation	3	0	3	6
Controls	0	0	6	6
Postmortem examination				
Phrenicectomy	3	0	3	6
Intercostal neurectomy	4	1	2	7
Rib fixation	1	0	5	6
Controls	0	2	4	6
			Total animals	25

CONCLUSIONS

It is realized that our series is too small to justify conclusions of far reaching importance; nevertheless it has given us a definite impression of the worth of these procedures.

1. It will be agreed that phrenicectomy is clearly of aid in setting the lung at rest and in enabling it better to combat disease.

2. Multiple intercostal neurectomy also should be a useful adjunct in accomplishing the same purpose, particularly in patients too ill to undergo more exhausting operations. It may well be used in connection with phrenicectomy.

3. The operation of rib splinting seems to be of value and warrants further investigation. Details of technic remain to be worked out to see whether the procedure may be adapted to human beings.

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THORACOPLASTY AND CONTRALATERAL ARTIFICIAL PNEUMOTHORAX*†

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BILATERAL pulmonary tuberculosis may be treated successfully by performing thoracoplasty in the presence of contralateral artificial pneumothorax. In the treatment of bilateral pulmonary involvement, compression therapy by artificial pneumothorax may be impossible or at best unsatisfactory on the more involved hemithorax. The compression may be impossible because of pleural symphysis, unsatisfactory because of partial pleural symphysis or because of extensive pleuropulmonary adhesions. Failure to establish an effective pneumothorax, which generally is on the more massively involved side, frequently means that it will be necessary to perform a thoracoplasty. This type of collapse therapy is indicated for eradication of cavitation and for collapse and subsequent arrest of active tuberculous lesions. Immediate radical surgical collapse, however, may be precluded because of the existing active pathologic condition contralaterally and attention should be directed toward the control of this contralateral lung involvement. Pneumothorax should be induced on the better side and conducted as an expansile type of compression for a sufficient period to warrant the application of more radical therapy of the hemithorax where pneumothorax could not be induced effectively. During this interval of delay of inducing surgical collapse, hemidiaphragmatic paralysis may be induced to control disease progression in the lung upon which thoracoplasty is contemplated. Whether or not phrenic exeresis is performed, should be decided individually, and this decision depends somewhat upon the character and distribution of the tuberculous process.

Bilateral pneumothorax which was once considered a rather radical procedure is at present used rather extensively. This type of compression was the result of the evolution of unilateral pneumothorax. This valuable procedure was a necessary development to allow the application of effective treatment to a group of patients in whom compression therapy had, under unilateral application only, been denied the benefit of compression therapy because of their bilateral tuberculosis.

Thoracoplasty in the presence of contralateral compression by artificial pneumothorax, we believe, is another step forward in the gradual evolu-

*Published by permission of the Surgeon General, U. S. Army.
†Cases reported before the Rocky Mountain Tuberculosis Conference, Colorado Springs, September 18 and 19, 1934.
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Received for publication, October 13, 1934.

tion of compression therapy. Unilateral compression by artificial pneumothorax was limited in its applicability because often the tuberculous process definitely involved both lungs. In the utilization of the procedure bilaterally, cases are encountered where pneumothorax induction on one side is impossible. Should we stop here, there would be a limited number of patients with advanced disease to whom satisfactory therapy would be denied. We advocate for this group the induction of pneumothorax with subsequent surgical collapse of the hemithorax where pneumothorax was found impossible or ineffective.

Often the application of compression therapy in a more selective manner not only makes possible the employment of bilateral compression but makes its utilization far less radical. The contralateral pneumothorax is conducted as an expansile type of compression, and the thoracoplasty is performed by a method which collapses only that portion of the lung actually necessitating surgical collapse. This is accomplished by performing a subtotal costectomy of a sufficient number of ribs to extend below the area of pulmonary involvement. This type of thoracoplasty accomplishes the required collapse yet leaves the relatively uninvolved portion of the lung uncollapsed and free for respiratory function.

We first attempted this procedure in 1931 and since that date have operated on 12 patients without a single operative death. Four of the cases required a two-stage operation, and 8 patients were operated on by one-stage operations. In none of these cases did we encounter any operative or postoperative difficulty in the nature of surgical shock. In the 12 cases, the result of pneumothorax therapy was excellent, for in no case did a cavity remain patent, while on the thoracoplasty side, cavities were closed in 10 cases and greatly reduced in size in 2 cases.

It is believed that great care should be used in the selection of cases for thoracoplasty when there is an induced pneumothorax contralaterally. The surgical collapse should be accomplished with great caution, resecting only as many ribs as the patient will endure without surgical shock. Prior to the operation, the contralateral lung is allowed to reexpand somewhat, and very small frequent pneumothorax refills are given during the postoperative convalescence. Only sufficient compression is maintained to prevent pleural symphysis during this period, increasing the compression as the patient establishes his convalescence.

It is a matter of judgment as to when the thoracoplasty should be performed, and, in instances, it is rather a difficult decision to make. In the case of V. P., we performed the thoracoplasty on the right side one month after induction of the artificial pneumothorax on the left side. In this case pneumothorax was impossible on the right side because of pleural symphysis, and collapse of the right upper lobe was imperative because of repeated severe pulmonary hemorrhage from an enlarging excavation. In the case of R. M., a pneumothorax was induced on the right side in 1932, and the thoracoplasty was not performed until

THORACOPLASTY AND CONTRALATERAL ARTIFICIAL PNEUMOTHORAX*†

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BILATERAL pulmonary tuberculosis may be treated successfully by performing thoracoplasty in the presence of contralateral artificial pneumothorax. In the treatment of bilateral pulmonary involvement, compression therapy by artificial pneumothorax may be impossible or at best unsatisfactory on the more involved hemithorax. The compression may be impossible because of pleural symphysis, unsatisfactory because of partial pleural symphysis or because of extensive pleuropulmonary adhesions. Failure to establish an effective pneumothorax, which generally is on the more massively involved side, frequently means that it will be necessary to perform a thoracoplasty. This type of collapse therapy is indicated for eradication of cavitation and for collapse and subsequent arrest of active tuberculous lesions. Immediate radical surgical collapse, however, may be precluded because of the existing active pathologic condition contralaterally and attention should be directed toward the control of this contralateral lung involvement. Pneumothorax should be induced on the better side and conducted as an expansile type of compression for a sufficient period to warrant the application of more radical therapy of the hemithorax where pneumothorax could not be induced effectively. During this interval of delay of inducing surgical collapse, hemidiaphragmatic paralysis may be induced to control disease progression in the lung upon which thoracoplasty is contemplated. Whether or not phrenic exeresis is performed, should be decided individually, and this decision depends somewhat upon the character and distribution of the tuberculous process.

Bilateral pneumothorax which was once considered a rather radical procedure is at present used rather extensively. This type of compression was the result of the evolution of unilateral pneumothorax. This valuable procedure was a necessary development to allow the application of effective treatment to a group of patients in whom compression therapy had, under unilateral application only, been denied the benefit of compression therapy because of their bilateral tuberculosis.

Thoracoplasty in the presence of contralateral compression by artificial pneumothorax, we believe, is another step forward in the gradual evolu-

*Published by permission of the Surgeon General, U. S. Army.

†Cases reported before the Rocky Mountain Tuberculosis Conference, Colorado Springs, September 18 and 19, 1934.

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Received for publication, October 13, 1934.

tion of compression therapy. Unilateral compression by artificial pneumothorax was limited in its applicability because often the tuberculous process definitely involved both lungs. In the utilization of the procedure bilaterally, cases are encountered where pneumothorax induction on one side is impossible. Should we stop here, there would be a limited number of patients with advanced disease to whom satisfactory therapy would be denied. We advocate for this group the induction of pneumothorax with subsequent surgical collapse of the hemithorax where pneumothorax was found impossible or ineffective.

Often the application of compression therapy in a more selective manner not only makes possible the employment of bilateral compression but makes its utilization far less radical. The contralateral pneumothorax is conducted as an expansile type of compression, and the thoracoplasty is performed by a method which collapses only that portion of the lung actually necessitating surgical collapse. This is accomplished by performing a subtotal costectomy of a sufficient number of ribs to extend below the area of pulmonary involvement. This type of thoracoplasty accomplishes the required collapse yet leaves the relatively uninvolved portion of the lung uncollapsed and free for respiratory function.

We first attempted this procedure in 1931 and since that date have operated on 12 patients without a single operative death. Four of the cases required a two-stage operation, and 8 patients were operated on by one-stage operations. In none of these cases did we encounter any operative or postoperative difficulty in the nature of surgical shock. In the 12 cases, the result of pneumothorax therapy was excellent, for in no case did a cavity remain patent, while on the thoracoplasty side, cavities were closed in 10 cases and greatly reduced in size in 2 cases.

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1934. In this instance, inhibition oleothorax had been instituted on the left side, lesions were stationary, and there was no reason to attempt radical surgery until the tuberculous process of the right lung was definitely arrested. We have a patient awaiting operation now who has had pneumothorax on the right for two years with a 3 cm. cavity in the midlung left. The cavity has a definite fibrous wall and has remained unchanged in size by hemidiaphragmatic paralysis. Soon we can allow the right lung to reexpand completely or certainly to reexpand sufficiently to lessen the dangers of respiratory difficulty at which time radical collapse of the left hemithorax can be induced. There can be no definite interval between the two procedures as each case presents a somewhat different aspect, and for this reason cases should be conducted individually. There should always be some definite reason for use of the two procedures simultaneously. Patients in whom the compression by pneumothorax and the collapse by thoracoplasty can be induced alternately are doubtless better operative risks. We must bear in mind, however, that unwarranted delay, in certain instances, may result in pulmonary complications of a character to preclude any surgical attempt at pulmonary collapse. Pulmonary cavities showing cavity wall reaction or which show a tendency to enlarge are the potential site of pulmonary hemorrhage, and any attempt to control or eradicate a cavity of this type is a justifiable procedure.

The selection of cases, from the standpoint of operative risks, is even more important than when cases are selected for an ordinary thoracoplasty. All our patients were given a routine preoperative medical survey consisting of electrocardiogram, vital capacity, special cardiac reserve estimation, blood chemistry, blood typing, blood count and coagulation time. In any given case selected for operation, it is well to know the electrocardiographic findings, how the heart responds to physical effort, and the vital capacity. To date, no tests give us an accurate estimate as to how any particular patient will endure major surgery. We have no test better than the judgment of a good physician if that judgment is exercised after long and close contact with the patient. The opinion of the attending physician who has known and examined the patient at frequent intervals is valuable in determining the operative risk. Careful selection of cases, proper preoperative precautions, surgical technic, and excellent postoperative care—each has an importance in successful thoracic surgery. We have come more and more to believe that none of the above factors can be ignored. There has not been an operative death from thoracoplasty at Fitzsimons Hospital during the past year, and we believe that this most unusual record has not been without attention to details on the part of both the physician and the surgeon. Here, as in most thoracic surgical clinics, the physician and the surgeon work in close harmony throughout the entire course of the treatment. Estimate of surgical shock at operation is determined by the physician, and this

arrangement should limit the surgical procedure to that endurable by the patient without manifest surgical shock.

Thoracoplasty may be successfully performed in the presence of an induced contralateral pneumothorax. An upper stage thoracoplasty consisting of subtotal costectomy of the upper five ribs may be performed in the presence of considerable contralateral pulmonary compression by artificial pneumothorax. A complete thoracoplasty may be performed, by a multiple stage operation, when the contralateral compression is conducted as an expansile type of pneumothorax.

Patients with a vital capacity of 40 per cent of normal or above should experience little operative or postoperative respiratory difficulty. One patient with a vital capacity of 20 per cent of normal was operated on without fatality, and following the reexpansion of the contralateral pneumothorax he was ambulatory without severe dyspnea.

All patients receive orally glucose preoperatively for twenty-four to forty-eight hours and sodium amytal orally to the amount of 6 grains. Gas oxygen anesthesia is used routinely, and normal saline is administered during the operation. Caffeine sodium benzoate in doses of 6 grains is used if stimulation is required.

Postoperatively a shock enema is given immediately; oxygen is given in an interrupted method; frequent lung inflation is practiced; the position of the patient is changed at frequent intervals, and morphine is administered for pain.

OPERATIVE HISTORY OF CASES

R. M., aged thirty years. Pneumothorax was induced on the right March 1, 1932, and on the left April 22, 1932. Obliterative pneumothorax developed on the right; phrenic exeresis was performed August 6, and inhibition oleothorax was instituted. The upper lobe cavity remained patent and a two-stage thoracoplasty was performed, first to fourth ribs inclusive Jan. 22, 1934, and fifth to eighth ribs inclusive March 24, 1934. Thoracoplasty was performed in the presence of a contralateral pneumothorax without operative or postoperative difficulty. Vital capacity preoperatively was 20 per cent of normal.

H. E., aged thirty-one years. Pneumothorax was induced on the left Aug. 25, 1933, and attempted on the right but pleural symphysis prevented its induction. Phrenic exeresis was not utilized but a thoracoplasty was performed, first to fifth ribs were resected inclusive. Prethoracoplastic vital capacity was 43 per cent of normal. There was no operative or postoperative difficulty.

A. P., aged twenty-five years. Pneumothorax was induced Dec. 11, 1931, on the left side and on the right side Jan. 5, 1932. Cavitation remained patent on the left because of pleuropulmonary adhesions. Intrapleural pneumolysis with cauterization of adhesions was performed March 3, followed by bronchopleural fistula which remained open sufficiently long (forty-eight hours) to infect secondarily the left pleural cavity. Pyothorax developed within a few days and disinfection oleothorax was induced immediately (March 5). Purulent exudate became a serofibrinous exudate, and the oleothorax was discontinued, and the exudate was removed by repeated aspirations. The pneumothorax space was gradually obliterated from below upward. When no more exudate formed, there existed a pneumothorax pocket over the upper lobe. Patent cavities were still present in the upper lobe, and on

March 14, 1934, selective compression oleothorax was induced completely filling the pneumothorax pocket. Several days after induction of the oleothorax, a pleurobronchial fistula developed, and the patient expectorated the oil. This was followed by a localized pyothorax. Upper stage thoracoplasty was performed resecting first to fourth ribs on April 2, and fifth to eighth ribs inclusive on April 18. During all of these procedures, the contralateral pneumothorax was carried on without difficulty. It

Fig. 1 Fig. 2.

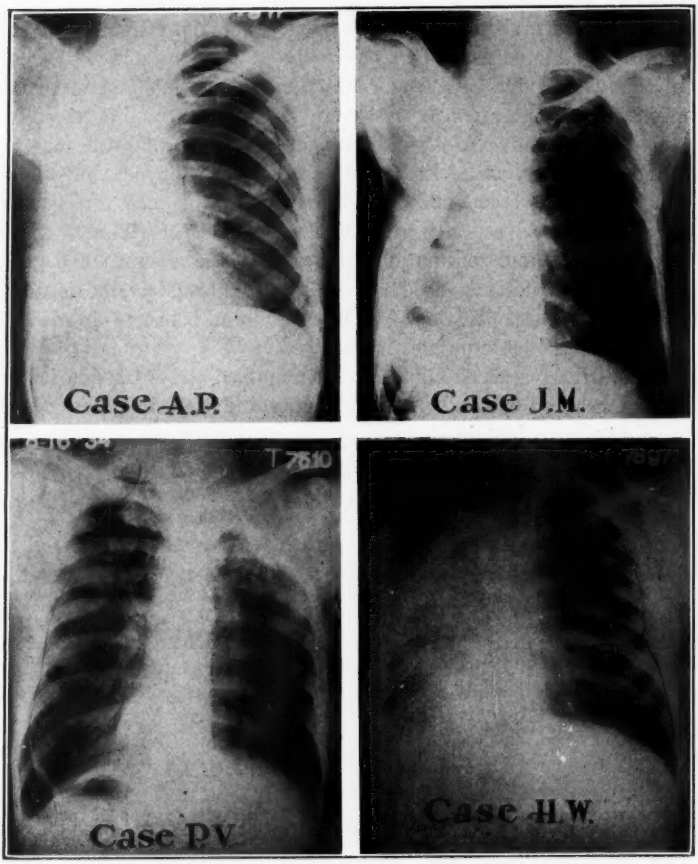

Fig. 3. Fig. 4.

will be noted that this case has had all the usually employed procedures of collapse therapy. Vital capacity was 53 per cent of normal. (Fig. 1.)

C. S., aged forty-two years. Pneumothorax was induced on the left side Jan. 11, 1933, and on the right side April 9, 1933. Pleural symphysis existed over the upper lobe left, and a phrenic exeresis was performed Feb. 2, 1933. Cavity remained patent and a thoracoplasty was performed in the presence of a contralateral pneumothorax resecting first to fifth ribs on Feb. 7 and sixth to seventh ribs inclusive on March 12. There was no operative or postoperative difficulty. Prethoracoplastic vital capacity was 52 per cent of normal.

A. R., aged forty-one years. Pneumothorax was impossible on the right side because of pleural symphysis. The left lung was relatively free of active disease. Thoracoplasty was performed on the right side March 25, 1933, resecting first to fifth ribs inclusive. Some months later there occurred a midlung bronchogenic spread in the left lung, and pneumothorax was induced in the presence of a thoracoplasty on the right. No difficulty resulted from the combination of the procedures. Vital capacity was 90 per cent of normal.

J. M., aged forty-five years. Pneumothorax was induced on the left side March 19, 1932, but a partial pleural symphysis caused the cavity to remain patent. Phrenic exeresis was performed as an adjunct to the pneumothorax on April 26, but after a long period of time the cavity remained patent. Further collapse therapy was objected to on the part of the patient. Contralateral disease, however, precluded thoracoplasty. Finally on March 23, 1934, a pneumothorax was induced on the right side and on May 18 a thoracoplasty was performed on the left, resecting first to sixth ribs inclusive. Vital capacity was 33 per cent of normal. No operative or postoperative difficulty. (Fig. 2.)

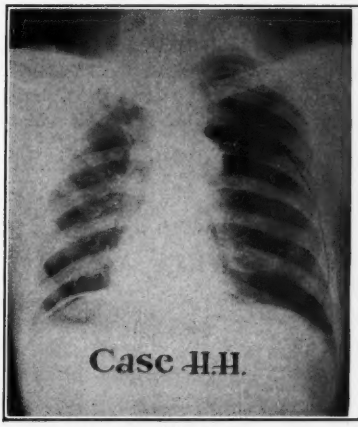

Fig. 5.

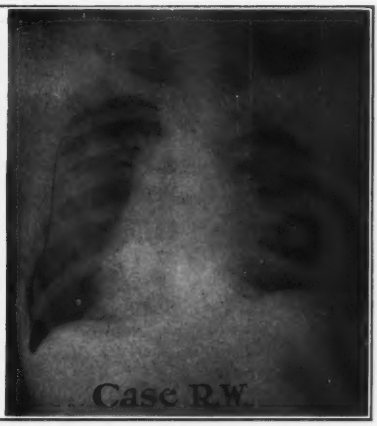

Fig. 6.

P. V., aged forty years. Pneumothorax was attempted on the right to control pulmonary hemorrhage from a cavity in the right upper lobe, but pleural symphysis precluded its induction. The hemorrhage subsided and checks by x-ray demonstrated a midlung aspiration tuberculosis in the left which precluded thoracoplasty on the right. It was then necessary to induce pneumothorax, which was done May 22, 1934. A thoracoplasty was then performed at an early date, June 22. Vital capacity was 68 per cent of normal. There was no operative or postoperative difficulty. (Fig. 3.)

H. W., aged thirty-five years. Pneumothorax was induced on the right side Dec. 8, 1933, and on the left Dec. 29. The pneumothorax on the left was unsatisfactory because of partial pleural symphysis. A thoracoplasty on the left was performed in the presence of a contralateral pneumothorax resecting first to fifth ribs inclusive on June 22, 1934, without operative or postoperative difficulty. Preoperative vital capacity was 60 per cent of normal. (Fig. 4.)

H. H., aged twenty-six years. Pneumothorax was induced on the right side Oct. 6, 1932, but was found impossible on the left because of pleural symphysis. A

phrenic exeresis was performed May 3, 1933, followed by thoracoplasty on the left side Dec. 5 resecting first to fifth ribs inclusive. Vital capacity was 53 per cent of normal. (Fig. 5.)

M. G., aged thirty-seven years. Pneumothorax induced on the left side June 27, 1933, and on the right April 4, 1934. The pneumothorax on the right was unsuccessful because of failure to collapse the cavity in the upper lobe. Upper stage thoracoplasty performed on the right Aug. 29, first to fifth ribs inclusive, without operative difficulty. Vital capacity 46 per cent of normal.

R. W., aged twenty-five years. Admitted with far advanced pulmonary tuberculosis. Right lung extensively involved with a 3 cm. × 4 cm. cavity in upper lobe. Bronchogenic spread in the left lung, extending well into periphery. Collapse therapy demanded for closure of the cavity, but this procedure alone was judged to be precluded because of the contralateral disease. Bilateral pneumothorax was attempted but found to be impossible on the right. (Fig. 6.) Phrenic exeresis was performed on the right side Aug. 11, 1931, and artificial pneumothorax induced on the left Nov. 17, 1931. Thoracoplasty performed on the right March 12, 1932, first to fifth ribs inclusive. Left pneumothorax was discontinued March 10, 1934. Sputum was negative and there has been no clinical evidence of active tuberculosis during the past year. (Case reported Am. Rev. Tuberc. **29:** March, 1934.)

G. M., aged twenty-two years. Bilateral far advanced pulmonary tuberculosis. Pneumothorax impossible on the right. Pneumothorax induced on the left May 5, 1931. Phrenic exeresis on the right June 25. Thoracoplasty on the right, first to fifth ribs inclusive, Dec. 19, 1931. Patient died of intestinal perforation March 26, 1934.

PHRENIC EXERESIS IN CONJUNCTION WITH ARTIFICIAL PNEUMOTHORAX THERAPY*

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PHRENIC exeresis has, within recent years, greatly increased as a procedure of compression therapy. The indications for its use have been increased to the extent that discussions of the procedure may well be limited to some particular indication for phrenic exeresis. While any discussion must of necessity contain a consideration of certain general principles involved, our discussion concerns chiefly the use of phrenic exeresis as an adjunct to artificial pneumothorax.

Phrenic exeresis is an important integral part of artificial pneumothorax therapy in pulmonary tuberculosis. The tuberculous patient undergoing or concluding treatment by pneumothorax should not be denied the benefit of hemidiaphragmatic paralysis of the hemithorax treated by pneumothorax unless adequate reasons can be presented to contraindicate the procedure, especially when the tuberculous involvement exists in the right lung.

Over a decade ago Alexander[1] stated, "It is my belief that the time will come when almost every artificial pneumothorax undertaken in the best clinics will be preceded or followed by phrenicotomy." We have performed phrenic exeresis in over 60 cases of artificial pneumothoraces as an adjunct to the procedure. This series of cases, though small, has resulted in observations and conclusions of no little significance in regard to the selection of cases and final results. True, similar observations and conclusions have been reported by others, but judging from the current medical literature the procedure certainly is not one of universal adoption. Restriction of its employment exists because there is disagreement as to the evaluation of the procedure when utilized as an adjunct to induced artificial pneumothorax. The procedures of collapse therapy have, in the past, been extensively used only after numerous workers have repeatedly presented their observations in a sufficiently conclusive manner. Since this has been true in regard to the various types of compression therapy, results of more recent methods or more recent phases of various procedures warrant discussion.

There has been considerable discussion as to the resultant intrathoracic alterations produced by phrenic exeresis and as to which of

*Published by permission of The Surgeon General, U. S. Army.
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Received for publication, September 24, 1934.

these altered conditions are the essential factors beneficial in causing or at least in assisting in arrest of the diseased foci. Some authors have stressed the importance of certain factors while others either have denied their existence or have certainly minimized the importance they play in the mechanism of compression. Many believe that the mechanism by which beneficial results are accomplished in pulmonary tuberculosis by hemidiaphragmatic paralysis involves the factors of relaxation, compression, and immobilization. Relaxation of involved lung is brought about by a reduction of lung volume following phrenic avulsion. The reduction of the lung volume follows the subsequent elevation of the diaphragm. This reduction varies somewhat in different cases but may be generally estimated at from one-sixth to one-third of the total lung volume. The abnormal tension on areas of lung tissue where pleural adhesions exist is further increased by lung contraction during the course of healing because of fibrotic changes and is relaxed by elevation of the diaphragmatic leaf. As in the case of artificial pneumothorax, compression and relaxation may initially be greatest in the lesser involved lower lobe. However, when sufficient time has permitted the more normal portion of the lung to demonstrate its expansile properties, the areas of the lung containing tubercles, which are undergoing progressive fibrotic changes, will show the effect of compression and relaxation to the greater degree.

Following avulsion of the hemidiaphragm's motor nerve, it either becomes immobile or moves in a paradoxical manner. Certainly, its active rhythmic contractions are eliminated, and the diaphragm can no longer regulate in its normal manner the differences in intrathoracic and intraabdominal pressure during the phases of respiration. Instead, it ceases to be a contending force and responds in a passive manner to these pressures so far as pathologic changes of diaphragm and pleurae will permit.

Compression of the more diseased portion of the lung ultimately results from paralysis of the diaphragm with its subsequent ascent into the hemithorax. The degree of compression obtained depends upon the extent of the diaphragmatic rise and upon the character of the pulmonary lesions. The ascent of the hemidiaphragm causes an immediate pulmonary compression which can be somewhat estimated as it is in proportion to the decrease in the longitudinal diameter of the hemithorax when the mediastinum and heart positions remain unchanged. Should these structures be displaced contralaterally, then the degree of pulmonary compression is proportionately lessened. In addition to the immediate rise, there follows a subsequent rise during the succeeding months or years. This secondary rise is the result of pulmonary contraction during the process of healing. Should the pulmonary lesions be of a character that fibrotic changes are already

far advanced at the time of phrenic exeresis, then the initial rise of the diaphragm will be less. Fibrotic lung involvement may resist compression by a force so slight as that exerted by mere diaphragmatic paralysis; also, the secondary rise will be minimal as pulmonary contraction has already taken place. Extensive consolidation, fibrotic changes, thick wall cavities, and rigidity of the bronchial tree resist compression by this particular type of compression therapy in a somewhat similar manner as noted in pneumothorax. The pulmonary compression ultimately obtained in suitable cases by phrenic exeresis is analogous to the selective type of pneumothorax therapy. Upon the induction of artificial pneumothorax, a selective type of compression is rather unavoidably obtained when applied to a case with upper lobe involvement of nodose caseofibrous tuberculous lesions. During and immediately following the introduction of gas the uninvolved lower lobe is easily compressible and may present greater compression than the upper lobe. Because the more normal lung area has far greater expansile property, it soon tends to reexpand, distributing the unabsorbed gas over the upper lobe which acts as a greater compression force to collapse ultimately the diseased area. The diseased area once compressed does not readily reexpand. It does not tend to reexpand so readily because there has been destruction of lung parenchyma, the air-containing tissue has been reduced, and thus its expansile power is greatly diminished. The compressed upper lobe, when observed fluoroscopically, remains practically stationary; the lower lobe is seen to be expansile. The upper lobe remains compressed because atmospheric air entering the upper bronchus does not expand the lobe because of the lack of air-containing tissue and because the negative pressure of the hemithorax, as a factor of expansion, has been reduced. After there has been sufficient time for the adjustment of compression following diaphragmatic paralysis, a similar distribution of pressure with ultimate greater compression of the involved lobe is assumed to exist. Compression of the diseased lobe in either instance approaches somewhat a partial atelectasis with diminution of function which allows increasing fibrosis and further contraction with even greater loss of expansile property.

Van Allen[2] believes the relative collapse obtained by artificial pneumothorax and that obtained by phrenic avulsion are not analogous. He believes the collapse obtained by phrenic exeresis has the characteristic of an elastic recoil rather than the shrinkage of an inelastic substance as occurs in artificial pneumothorax.

Immobilization of the hemidiaphragm was given as one of the factors beneficial in obtaining results from phrenic exeresis. It is through immobilization and rise of the hemidiaphragm that relaxation and compression are obtained. The effect of the immobilization as a factor of pulmonary rest, however, is considered important. A functioning

hemidiaphragm makes from 20,000 to 30,000 excursions in twenty-four hours; a paralyzed diaphragmatic leaf relieves the diseased lung functionally through its immobility.

As in other procedures of collapse therapy utilized in the treatment of pulmonary tuberculosis, there is some variation of opinion as to just what factor produces the desired results. Matson[3] states: "The results of an induced hemidiaphragmatic paralysis are more dependent upon the rise of the diaphragm and the degree of collapse of the diseased lung tissue affected thereby, than upon merely placing the diaphragm at rest. The best results have always been associated with a marked rise of the diaphragm and the poorest results have been in the cases in which little or no rise of the diaphragm took place." Slavin,[4] in discussing the closure of tuberculous cavities by combined artificial pneumothorax and phrenicectomy, states: "Closure of the cavity is not influenced by the amount of elevation of the paralyzed diaphragm. The latter may descend under high pressures to levels lower than before the phrenicectomy, but obliteration of the cavity continues unhindered." Coryllos[5] discusses the factors now under discussion as follows:

1. Compression.—There is a slight decrease in the capacity of the chest equal to compression obtained by 200 to 300 c.c. of air, and it will not produce an effective degree of pulmonary collapse.
2. Relaxation.—"I confess that I cannot understand its mechanism."
3. Immobilization.—"Much less important than is generally believed."

Alexander[1] states: "The effect then of radical phrenicectomy is the marked curtailment of the respiratory activity of a hemithorax and a diminution of the capacity of that side of the chest causing a relaxation of the lung."

O'Brien[6] states, "Paralysis of the diaphragm causes it to thin out and rise into the chest, stops its pumping action, releases elastic tension of the lung due to negative pressure within the thorax, and also the pull of contracting fibrous tissue, and gives added rest and compression by the upward force of intraabdominal pressure."

We believe that paralysis of the hemidiaphragm whether performed as a compression procedure alone or in the presence of artificial pneumothorax, assists in the healing of pulmonary tuberculosis when applied to suitable cases. Paralysis of the diaphragm with its subsequent rise into the hemithorax assists in healing because it produces pulmonary compression and relaxation, and gives additional pulmonary rest because of immobilization of the diaphragmatic leaf.

The results obtained by the procedure depend upon the degree of compression, relaxation, and immobilization obtained. These factors which yield the desired results can be somewhat estimated in advance by careful study of the existing pulmonary pathologic condition as

to the duration and character of lesions, evidence of preexisting serous effusion or fibrous pleurisy, and the diaphragmatic mobility observed fluoroscopically. In the presence of artificial pneumothorax, an estimation of beneficial results may be more accurately prognosticated, for the presence or absence of pleural adhesions or partial pleural symphysis may be readily observed. In pneumothorax cases it is extremely important, for satisfactory results, to select cases with a symphysis or partial symphysis of the basal visceral pleura and diaphragmatic pleural surfaces. Gas between the pulmonary base and the diaphragm hinders pulmonary compression in that the diaphragm fails to ascend into the hemithorax subsequent to the hemidiaphragmatic paralysis. In the latter instance the maximum rise is not obtained until the gas refills are discontinued and the gas in the hemithorax has been allowed to absorb. The condition just described does not contraindicate phrenic exeresis as favorable results are often obtained; however one must then rely upon the factors of relaxation and immobilization for therapeutic results. The obtaining of favorable results in the absence of one factor or the other has led us to believe that the three factors discussed are each of importance. Their relative importance has, as yet, not been ascertained sufficiently to warrant a definite comparative evaluation. We believe that phrenic exeresis is a very important adjunct of artificial pneumothorax therapy. Although pulmonary compression and relaxation are already present, they are increased and the factor of diaphragmatic immobility is added. The increase of these etiologic factors of compression therapy, of course, depends upon the selection of cases, that is, upon factors already discussed, such as pulmonary pathologic condition, pleural involvement, mobility of the diaphragm, and the extent of pulmonary diaphragmatic pleural symphysis. Often pulmonary compression and relaxation have not been satisfactorily obtained because of pleural adhesions which cause cavities to remain patent. Certainly undue tension is placed upon areas of the lung which may contain progressive tuberculous lesions. Attempts to increase compression by the administration of greater quantities of gas, if continuously conducted, may lengthen pleuropulmonary adhesions without complications. The complications of this procedure, however, may be severe in character, and we believe that accomplishment of satisfactory compression and relaxation can be obtained by phrenic exeresis without the dangers attendant upon higher pressures by pneumothorax. Higher pressures by pneumothorax, when pleural adhesions interfere with compression, may produce pleural effusion, ruptured lung parenchyma or cause active lesions at the pulmonary attachment of pleural adhesions to ulcerate through the visceral pleura producing a bronchopleural fistula. We have concluded from postmortem study that in cases of superimposed spontaneous pneumothorax complicating artificial pneu-

mothorax which terminate in death because of a patent bronchopleural fistula, the fistulous tract is very often situated at the site of pulmonary attachments of pleural adhesions. The adhesions formed originally because pulmonary lesions approximated the visceral pleura so closely that their perifocal reaction involved the parietal pleura. Undue tension upon the area of active pulmonary involvement, because of countertraction of adhesions, not only defeats the primary purpose of compression therapy but may be harmful, in that tuberculous lesions are caused to progress to ulceration and rupture through the visceral pleura. Active tubercles in the wall of subpleural cavities may, in the same manner, through tension, ulcerate to connect the pulmonary cavity with the pleural cavity. It seems far safer to obtain relaxation of the area under tension due to countertraction of offending adhesions, by diaphragmatic paralysis. Phrenic exeresis often becomes essential to close cavities of basal, central, or hilar location. The application of phrenic exeresis as an adjunct to artificial pneumothorax not only greatly assists in obtaining and maintaining the necessary compression, relaxation and rest of the diseased lung during the course of active compression therapy, but also acts as an advantage during and after pulmonary reexpansion. It is of benefit during and after reexpansion because the elevation of the diaphragm so reduces the hemithorax that the extent of pulmonary reexpansion is greatly lessened. Areas of the lung once tuberculous do not have to undergo or cannot undergo complete reexpansion. The heart and mediastinum are not pulled to the affected side to compensate for the inability of the lung to reexpand properly. The lung once diseased is not allowed to function as much because of diaphragmatic immobility. The loss of respiratory function of the hemithorax produced by hemidiaphragmatic paralysis is not fully compensated by an increase in function of other respiratory muscles.

O'Brien,[6] in discussing the indications for phrenic exeresis, states: "When adhesions to the lateral wall or apex prevent proper collapse, especially if the base of the partially collapsed lung is adherent to the diaphragm and it seems that the ascent of the diaphragm into the chest will relax them and allow a continuation of the pneumothorax to cause further collapse of the lung." He gives, also, as an indication pulmonary reexpansion when pneumothorax is completed. Edwards[7] states, "In artificial pneumothorax cases where adhesions hold out cavities in the middle area, the raising of the diaphragm causes the cavity to obliterate without the necessity of cauterization." Bronfin,[8] in enumerating the indications for phrenic exeresis in order of importance, places in fourth place, "Two supplement pneumothorax by relaxing adhesions preventing effective collapse." Trudeau,[9] in writing of phrenic exeresis in conjunction with artificial pneumothorax, states,

"This is usually done when satisfactory results are not obtained from artificial pneumothorax treatments, because of adhesions causing insufficient or useless collapse." He also gives reexpansion as an indication. Dundee,[10] believes the time to perform phrenic exeresis is some weeks after the last pneumothorax refill, when the intrapleural pressure becomes highly negative and before displacement of the mediastinum occurs and before the pleural surfaces become adherent.

Slavin[4] concluded, after a review of a series of 28 cases, "Cavities attached to the parietal pleura by fixed string or band adhesions can be collapsed by pneumothorax with added phrenicectomy."

Considered from a broad viewpoint, phrenic exeresis as an adjunct or supplement to artificial pneumothorax is indicated in practically every case of artificially induced pneumothorax. It is indicated because it is an aid in obtaining a certain desirable pulmonary status essential to ideal results of compression therapy. It aids in maintaining a better state of compression, relaxation and rest during the active phase of the therapy and acts as an agent to reduce displacement of intrathoracic structures during reexpansion. It serves as a safety factor to prevent subsequent reactivation of tuberculous lesions because it lessens the degree of lung reexpansion and decreases pulmonary function. More conservative indications for phrenic exeresis in conjunction with pneumothorax as an adjunct or supplementary procedure may be enumerated as follows:

1. When pleuropulmonary adhesions cause cavities to remain patent.
2. When a complicating obliterative pleuritis tends to obliterate the pneumothorax space.
3. During pulmonary reexpansion after completion of successful pneumothorax therapy.
4. In pneumothoraces of an unsatisfactory character resulting from partial pleural symphysis.
5. To close basal, central, or hilar cavities which remain patent after the induction of pneumothorax though there are no apparent pleural adhesions.

Since the indications enumerated above include that of pulmonary reexpansion following the completion of a successful artificial pneumothorax, they really include all cases of artificial pneumothorax therapy. We do not wish, however, to advocate the adoption of any procedure of compression therapy as a hard and fast routine. Procedures of therapy must, of necessity, be applied to individuals and not to case groups.

For convenience of discussion we have divided our series of cases into case groups corresponding to the five indications as enumerated above. In Group I in Table I are shown cases of artificial pneumothorax with cavities remaining patent after an attempt to close them

by induced pneumothorax. The cavities remain patent because of pleuropulmonary adhesions. Phrenic exeresis was performed as an adjunct to the pneumothorax in an attempt to assist cavity closure.

TABLE I

GROUP I

CASE	DURATION IN MONTHS OF PERIOD OF OBSERVATION			CAVITATION		ELEV. DIAPH.	EXT. DIAPH.	RESULT
	PNEUMOTHORAX OBS.	PNEUMO.	PHRENIC PHREN.	SIZE CM.	SITE LOBE	CM.	SYMP.	
CF	47	47	14(R)	Small mult.	UL	3	⅔	Satisfactory
NS	16	16	11(R)	3	UL	10	⅔	Excellent
LB	18	18	11(R)	3.5	UL	8	Total	Excellent
AE	25	23	17(R)	3	UL	3	⅔	Satisfactory
EZ	32	32	18(R)	Small mult.	UL	4.5	½	Satisfactory
CE	18	18	15(L)	6	UL	7	½	Unimproved
GJ	18	18	14(R)	3.5	UL	5	Total	Excellent
MH	58	50	13(R)	2.5	UL	2	¾	Excellent
AG	28	27	26(R)	3	UL	2	Total	Satisfactory
SD	62	61	19(R)	Small mult.	UL and ML	4	½	Satisfactory
RL	21	21	13(R)	6	UL	None	Total	Excellent
NC	30	29	28(L)	7	ML	9	½	Excellent
CC	42	41	27(R)	6	UL	None	⅛	Unimproved
FY	15	15	7(R)	3.5 and mult.	UL	1	½	Excellent
AN	14	14	12(L)	3	UL	8	⅔	Improved
GE	17	17	5(R)	Small mult.	UL	5	⅔	Excellent
AF	18	12	11(R)	Small mult.	UL	5	⅔	Satisfactory

ANALYSIS AND DISCUSSION OF GROUP I

The group consists of 17 patients, 14 having had pneumothorax and phrenic exeresis on the right and 3 on the left. The maximum rise of the diaphragm observed was 10 cm., while 2 cases showed no elevation. The average rise for the group was 4.4 cm. Eight cases are classed as excellent as to results because the cavitation closed within a period of six months or less; 6 cases are classed as satisfactory because the cavity closed within twelve months; 2 cases are classed as unimproved because the cavity did not show a reduction in size because of large, extensive adhesions which required cauterization; 1 case is classed as improved because the cavity, while not closed at the time the patient left our observation, was greatly reduced in size. Therefore, excellent results were obtained in 47.05 per cent of Group I, satisfactory results in 35.3 per cent, improved in 5.88 per cent, unimproved in 11.76 per cent.

It is interesting to note that of the two cases showing no elevation of the diaphragm, one case showed excellent results and one case was

unimproved. Both patients had rather large cavities in the right upper lobe with adhesions rather comparable as to their location and extent. It should be noted, however, that in the case showing excellent results the patient had a total symphysis of the lung to the diaphragm, while the unimproved patient showed the diaphragmatic symphysis to exist only over the mesial third of the diaphragm. We believe that the extent of diaphragmatic symphysis is an important aid in bringing about the factors essential to obtain satisfactory results.

All the cases of the group are classified as *far advanced.* This classification is made because the tuberculous infiltration of the lung amounts in extent to the volume of one lung and the process is complicated by cavitation 2 cm. or more in diameter or cavitation is multiple in character.

Slavin[4] has offered an explanation of the mechanism by which phrenic avulsion permits the closure of upper lobe cavities, in pneumothorax cases, which remain patent because of pleural adhesions. He believes that under normal conditions the lung compressed by pneumothorax displaces an upper lobe cavitation downward because the pulmonary retraction is toward the fixed lung attachment, namely, the hilum. With the presence of a pleural adhesion preventing closure of the cavity, a second fixed point of lung attachment is present, namely, the adhesion itself. With an active diaphragm, tension toward the root of the lung dominates over the contraction capacity of the stretched adhesions. Following paralysis of the hemidiaphragm, there is a gradual relaxation of the treated lung and abatement of its tension toward the root. Tugging on the cavity ceases and its compression proceeds toward the attachment of the adhesion. We believe that in this particular group relaxation obtained by paralysis of the diaphragm is the most important phase of the therapy. Compression is also a factor, and the elevation of the diaphragm becomes more important during the reexpansion period when the rise is of a secondary character because of pulmonary contraction following healing. This rise then prevents displacement of thoracic viscera. Immobilization plays a part as a safety factor in that it decreases pulmonary function.

In Group II in Table II are shown cases with massive pleural adhesions or cases developing an extensive obliterative pleuritis with newly formed adhesions. In these cases, pneumothorax therapy soon becomes impossible or at best is of an unsatisfactory duration. The complication of an acute pleurisy with a serous effusion tends, especially during the resorption period, to form new and extensive adhesions. These new adhesions contract and reduce the pneumothorax space. The approximation of pleural surfaces during acute pleuritis ends in pleural symphysis. When the pneumothorax is unsatisfactory

or becomes so during the course of the therapy, phrenic exeresis is indicated. Preexisting adhesions may obliterate the space by contraction during refill intervals. Obliterative pneumothorax may appear within a short time without x-ray evidence of pleural adhesions. We have frequently observed the lung suddenly to become adherent to the anterior or posterior chest wall followed by progressive reexpansion and obliteration of the pneumothorax space. These complications

TABLE II

GROUP II

CASE	DURATION IN MONTHS OF PERIOD OF OBSERVATION			CAVITATION		ELEV. DIAPH.	EXT. DIAPH.	RESULT
	PNEUMOTHORAX OBS.	PNEUMO.	PHRENIC PHREN.	SIZE CM.	SITE LOBE	CM.	SYMP.	
HJ	16	14	10	Small mult.	UL	10	None	Unimproved
RE	13	5	9	2.5	UL	2	⅔	Excellent
WJ	18	7	3	None		3	⅔	Satisfactory
FD	24	14	11	Mult. small	UL	8	Total	Satisfactory
LR	47	18	16	Mult. small	Mid lung	10	Total	Unimproved
CS	42	42	11	Small mult.	UL	1	Total	Unimproved
AF	84	30	10	4	Lower	Not visible	Total	Satisfactory
RH	18	18	9	5	UL	10	Total	Satisfactory
JC	16	12	9	2.5	UL	Fluid	Total	Excellent
LW	19	17	14	Small mult.	UL	2.5	½	Excellent
HD	12	12	1	None		3	½	Improving
IH	16	14	2	None		5	⅔	Improved

may occur earlier in pneumothorax therapy when pulmonary lesions are yet active and when cavities remain patent. In instances, radical surgical collapse is indicated, but in many cases a simple phrenic exeresis applied early will avoid the institution of more radical procedures. Phrenic exeresis performed as soon as there is evidence of obliterative pleuritis allows maximum elevation of the diaphragm, while unwarranted delay allows the formation of additional basal adhesions which limit diaphragmatic elevation.

ANALYSIS AND DISCUSSION OF GROUP II

The group consists of 12 cases. Excellent results were obtained in 3 cases, satisfactory results in 4 cases, improvement or improving in 2 cases, and 3 cases were unimproved. Cavities were closed in 7 cases and the cavity remained patent in 2 cases. Highest elevation of the diaphragm was 10 cm. (2 cases) with an average elevation of 5.8 cm. Two cases presented pleural effusion, and the position of the diaphragm could not be accurately determined. All cases of the group are clas-

sified as far advanced. In this group, results are not so satisfactory as those obtained by phrenic exeresis applied when single or multiple adhesions of the upper lobe prevent cavity closure. Results, however, are in general satisfactory and in instances prevent recourse to more radical surgery.

TABLE III

GROUP III*

CASE	DURATION IN MONTHS OF PERIOD OF OBSERVATION			ORIGINAL CAVITATION		ELEV. DIAPH.	EXT. DIAPH.	RESULT
	PNEUMOTHORAX OBS.	PNEUMO.	PHRENIC PHREN.	SIZE CM.	SITE LOBE	CM.	SYMP.	
GO	35	30	6	Small mult.	UL	3	⅔	Satisfactory
HP	31	30	13	2	UL	4	Total	Satisfactory
RM	25	23	6	3	UL	4.5	Total	Satisfactory
AP	30	14	12	3	LL	5	Total	Satisfactory
JK	40	32	10	3.5	UL	7	Total	Satisfactory
ER	46	28	10	Small mult.	UL	2.5	Total	Satisfactory
FL	29	14	13	5×7	UL	3	Total	Died of contra lateral lung involvement
FH	44	32	14	5	UL	3	Total	Satisfactory
RH	37	27	6	2	UL	3.5	Total	Satisfactory
AC	34	26	12	Small mult.	U and ML	6	Total	Satisfactory
GB	43	30	23	2	UL	3	Total	Satisfactory
FB	20	12	5	None		8	Total	Satisfactory
MT	30	29	1	Small mult.	UL	3	Total	Satisfactory
HS	18	12	3	None	None	9	None	Satisfactory
CE	52	36	15	None	None	3	½	Satisfactory
WH	72	54	15	None	None	7	½	Satisfactory

*All these cases are classed as far advanced except the cases of FB and HS which are moderately advanced.

Group III cases tabulated in Table III are cases in which phrenic exeresis was performed as a preexpansion procedure. This group consists of 16 cases; however other patients have been so treated but have returned to their homes immediately after operation and results could not be studied by x-ray examination. In these cases, phrenic exeresis was performed either because pneumothorax therapy had been continued over a period sufficient to arrest the disease and reexpansion was contemplated or because contralateral pneumothorax was indicated and the original pneumothorax, though not of maximum duration, was discontinued and phrenic exeresis substituted. The latter procedure in carefully selected cases is sometimes more advisable than converting the case to bilateral pneumothorax, especially when the original pneumothorax has been continued just short of the average duration before the reactivation or progression of contralateral lung lesions occurs. The majority of the cases, however, are those of timely lung reexpansion, and phrenic exeresis was performed for its mechanical effects upon the treated hemithorax.

ANALYSIS AND DISCUSSION OF GROUP III CASES

Of the 16 cases tabulated, satisfactory results were obtained in 15 cases. One patient originally had large, bilateral cavitation. The contralateral lung lesions remained stationary, however, for approximately two years, but then lesions progressed rapidly and the patient died in spite of bilateral pneumothorax. Average rise of the diaphragm, including the secondary rise, was 4.9 cm.; highest rise was 9 cm. Although these cases are classed as reexpansion phrenic exeresis, the operation was performed, in most instances, far in advance of the lung reexpansion.

Phrenic exeresis is of undoubted value in the treatment of pulmonary tuberculosis. It is of value whether applied in conjunction with pneumothorax or used as the sole procedure of compression therapy. Since it is of value and is advocated as a preexpansion measure, it seems reasonable to advocate its use during the course of pneumothorax therapy so that when the therapy is no longer necessary and reexpansion is contemplated, the paralysis of the diaphragm already exists. It seems that by delay until the reexpansion stage, a valuable asset has been denied the patient.

Slavin,[11] in a recent article, in discussing cavity changes resulting from paralysis of the diaphragm states, "The immediate changes appearing in those cavities after phrenic paralysis are produced by two factors: (1) Compression exerted by the elevated diaphragm and (2) relaxation resulting from cessation of diaphragmatic movements." He further states, "As an aid in closure of pulmonary tuberculous cavities, phrenic paralysis presents the least radical procedure, and its application in selected cases saves the patient the inconvenience of prolonged pneumothorax treatment, the risk of major surgical collapse operations, and the uncertainty of protracted expectant therapy." We maintain that if diaphragmatic paralysis will materially aid in the closure of tuberculous pulmonary cavities, it will also aid the healing of noncavernous tuberculous involvement and will prevent the formation of cavities. If one agrees that pulmonary lesions tend to heal under the conditions of compression and relaxation, then the more ideal these factors exist the better the progress of healing. Diaphragmatic paralysis increases the compression and relaxation in artificial pneumothorax cases, and the combination of the two procedures yields desirable results with less protraction of pneumothorax therapy. Evidence of areas of tension because of adhesions or adherent lung, is sufficient to demand the procedure. We now advocate phrenic exeresis not as a preexpansion procedure, but as an adjunct to artificial pneumothorax in that better compression and relaxation are obtained. When pneumothorax refills are finally discontinued, it affords beneficial factors already discussed.

Group IV, tabulated in Table IV, consists of 7 cases. These patients presented pleural symphysis over the upper lobe which prevented collapse of the diseased areas by artificial pneumothorax. When it was observed that pneumothorax was unsuccessful, phrenic exeresis was performed, usually within a few months, and the cases carefully observed. Pneumothorax was carried on in conjunction with the diaphragmatic paralysis as long as possible. These cases were all classi-

TABLE IV

GROUP IV

CASE	DURATION IN MONTHS OF PERIOD OF OBSERVATION			CAVITATION		ELEV. DIAPH.	EXT. DIAPH.	RESULT
	PNEUMOTHORAX OBS.	PNEUMO.	PHRENIC PHREN.	SIZE CM.	SITE LOBE	CM.	SYMP.	
NR	23	23	21	6	UL	None	½	Progressive disease. Death.
JMcD	17	16	12	3	UL	5	None	Thoracoplasty necessary
GM	28	28	14	Mult. med.	UL	6	½	Thoracoplasty necessary
BJ	20	19	11	2	UL	5	½	Satisfactory
BH	14	9	4	2	UL	3	½	Satisfactory
HB	24	24	4	Small mult.	UL	3.5	½	Satisfactory
DC	30	30	17	Large mult.	UL	3.5	½	Satisfactory

fied as far advanced. In most instances the disease had existed over a rather long period without an attempt to induce compression therapy. As soon as the patients came under our care, pneumothorax therapy was attempted, but, as so frequently happens by an unwarranted delay, pleural symphysis had taken place and the involved lobe could not be compressed.

ANALYSIS AND DISCUSSION OF GROUP IV

Of the 7 cases, 4 patients showed a satisfactory result in that cavities were closed and the disease process became arrested. Two patients required a thoracoplasty to close the pulmonary cavitations. One patient continued to show disease progression and died. The highest rise of the diaphragm noted was 6 cm.; average elevation was about 3.5 cm. The patient who died showed no rise of the diaphragm. In one case, the base of the lung was not adherent to the diaphragm and most of the gas administered collected between the lung base and the diaphragm. No change was noted in pulmonary lesions or in the size of the cavity. Pneumothorax refills were discontinued and a thoracoplasty was performed. When the air was completely absorbed, the diaphragm, which had shown no elevation, became elevated 5 cm. in extent. In certain cases more beneficial results of compression and relaxation are obtained by discontinuing the pneumothorax after the

phrenic exeresis. When pneumothorax was found to be of an unsatisfactory character, the above cases appeared suitable for thoracoplasty. However, phrenic exeresis proved sufficient to arrest the disease in 4 cases out of 7. In cases of unsatisfactory pneumothorax, phrenic exeresis should be performed at an early date. If unsuccessful, a thoracoplasty should then be performed without unwarranted delay. In instances, patients are not suitable candidates for thoracoplasty because of unsatisfactory "surgical risk"; in other cases, paralysis of the diaphragm may aid in improving pulmonary disease, and their general condition may improve until they advance to the classification of a "surgical risk." In less advanced cases, the procedure yields results so satisfactory that surgical collapse is delayed and the patients continue to improve until disease arrest is obtained. This group of cases show less satisfactory results than any other group, but results have been sufficiently satisfactory to make the procedure advisable.

Group V, tabulated in Table V, consists of 8 cases. This group consists of cases in which, though no apparent adhesions held cavities

TABLE V

GROUP V

CASE	DURATION IN MONTHS OF PERIOD OF OBSERVATION			CAVITATION		ELEV. DIAPH.	EXT. DIAPH.	RESULT
	PNEUMOTHORAX OBS.	PNEUMO.	PHRENIC PHREN.	SIZE CM.	SITE LOBE	CM.	SYMP.	
WI	10	9	6	Mult. large	UL	9	Total	Died of intestinal perforation. Lungs improving.
JC	13	8	12	4	LL	7	2/3	Satisfactory
JD	24	13	22	3	ML	8	2/3	Excellent
ER	25	12	21	3	ML	7	2/3	Excellent
WJ	34	30	15	3	ML	5	2/3	Excellent
JF	12	11	4	Mult. med.	ML	None	Total	Died of pulmonary hemorrhage
GG	48	46	108	3	LL	3	2/3	Excellent
JM	27	23	9	Mult. med.	Both UL	8	2/3	Excellent

patent, cavities failed to obliterate under pneumothorax therapy. In instances, cavity closure was attempted by phrenic exeresis, and pneumothorax was later induced because the cavity failed to close. The 8 cases are cases in which pneumothorax and diaphragmatic paralysis existed simultaneously in that one or the other procedure had failed to accomplish cavity obliteration.

ANALYSIS AND DISCUSSION OF CASES OF GROUP V

Of the 8 cases of this group, excellent results were obtained in 5 patients, satisfactory results in 1 patient, and 2 patients died, one of

pulmonary hemorrhage and one of intestinal perforation of a tuberculous ulcer. The patient who died of pulmonary hemorrhage showed no elevation of the diaphragm, though there was total diaphragmatic symphysis. Four of the patients presented midlung cavities; 2 patients had lower lobe cavities; 1 patient had upper lobe cavity; 1 patient had cavities in both upper lobes with a bilateral pneumothorax. We have observed cavities to remain patent in the presence of an apparently satisfactory pneumothorax. Generally, the cavities have been situated in the midlung area where bronchi and blood vessels tend to inhibit the degree of pulmonary compression. The walls of the cavities were somewhat thicker than the average cavity wall, and the thickness was noted to be due to an increase in fibrous tissue rather than to reaction about pulmonary infiltration. We have found that when cavities remain patent after a period of moderate pulmonary compression by pneumothorax or fail to obliterate after a satisfactory period by diaphragmatic paralysis, the combination of the two procedures will often result in rapid obliteration of the excavation. The utilization of diaphragmatic paralysis as an adjunct to artificial pneumothorax because cavities remain patent, though apparently not because of pleuropulmonary adhesions, yields results of an excellent character in that cavities rapidly obliterate.

CONCLUSIONS

1. Hemidiaphragmatic paralysis is of value as a supplement to artificial pneumothorax therapy when additional pulmonary compression and relaxation are required for cavity obliteration because of pleuropulmonary adhesions.

2. Artificial pneumothorax complicated by acute pleuritis with or without serous effusion frequently ends in obliterative pneumothorax. Untimely obliteration of the pneumothorax space with pulmonary reexpansion will end in disease progression, and some procedure of compression therapy should be substituted for the pneumothorax lost through obliteration. We advocate that the next procedure instituted should be diaphragmatic paralysis.

3. After successful pneumothorax, diaphragmatic paralysis is indicated as a preexpansion procedure. The elevation of the diaphragm decreases the size of the hemithorax and thus reduces the degree of pulmonary reexpansion required, prevents mediastinal retraction, and causes a permanent continuation of some compression and relaxation. There is also the safety factor of decreased pulmonary function.

4. Hemidiaphragmatic paralysis aids in compression and relaxation when pneumothorax is of an unsatisfactory character because of pleural symphysis over the involved lobe or lobes. This simple procedure may prevent recourse to radical surgical collapse.

5. Hemidiaphragmatic paralysis is indicated when artificial pneumothorax, after a sufficient period, fails to obliterate midlung cavities, though no offending pleural adhesions are evident by x-ray examination.

6. We have concluded that diaphragmatic paralysis is of value when factors are present which tend to make artificial pneumothorax unsatisfactory and when, though the pneumothorax therapy has been successful, reexpansion of the compressed lung is contemplated. When factors are present which interfere with compression and relaxation of the treated lung, diaphragmatic paralysis has proved of value. If it is of value under unfavorable conditions, its value increases when unfavorable factors do not exist; and since it is of value as a preexpansion procedure, we see no reason why practically all cases of artificial pneumothorax should not be supplemented by diaphragmatic paralysis.

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THE EFFECT OF DIAPHRAGMATIC PARALYSIS UPON THE EFFICIENCY OF COUGH*†

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INTRODUCTION

CONSIDERABLE emphasis has recently been placed on impairment of diaphragmatic function as a contributing cause of postoperative pulmonary complications. Inasmuch as disturbance of the cough mechanism is a significant factor in the evolution of pulmonary sepsis, it is desirable to know to what extent a paralyzed or an inefficient diaphragm may interfere with the effectiveness of cough. This is a report of a study of the diaphragm in relation to the cough mechanism.

Disturbance of diaphragmatic function is commonly observed (1) in the paralysis induced for chronic suppurative disease of the lungs and (2) following abdominal operations, which cause greatly decreased mobility of the diaphragm. Since surgically induced paralysis renders the diaphragm a passive septum which presumably transmits in full the thrust of the intraabdominal pressure against the corresponding lung, we should anticipate no significant change in the efficiency of cough except so far as decrease in lung expansion diminishes the volume of air available for the expiratory blast. Whether or not this presumption is well founded is a matter of controversy. Carlson, Ballon, Wilson and Graham[1] report a retarded elimination of lipiodol from the lung of the paralyzed side as compared with that of the normal side in dogs and conclude that the efficiency of cough is decreased. Kinsella[2] states that phrenicectomized tuberculous patients who develop pulmonary complications after operations not related to the chest have more difficulty in expelling secretions from the lung than similar patients without phrenicectomy. On the other hand, Lilienthal[3] subscribes to the prevailing opinion that phrenic exeresis does not interfere with the efficiency of cough.

The conclusions of Carlson and his coworkers[1] that phrenicectomy retards the expectoration of lipiodol and diminishes the ability of dogs to cough foreign bodies from the bronchi of the same side are based chiefly on observations upon the effect of unilateral phrenicectomy. Our study is not concerned with expectoration, the total result of all

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†The expenses for this investigation were provided by the Proctor Fund of the Harvard Medical School.

Received for publication July 10, 1934.

the drainage mechanisms in the lung, but only with what happens to the force of the cough. For this purpose we felt it essential to paralyze both sides of the diaphragm in order to avoid the confusing situation during the expiratory effort created in unilateral paralysis by the paradoxical movement. With both sides paralyzed, the compressing force exerted upon the lung should be delivered in full and thus make it possible to determine what the diaphragm as a paralyzed muscular septum in and of itself does to the force exerted upon the lung by the abdominal thrust. The results of such an experiment, even if transferable to man, may not be related to the situation existing after

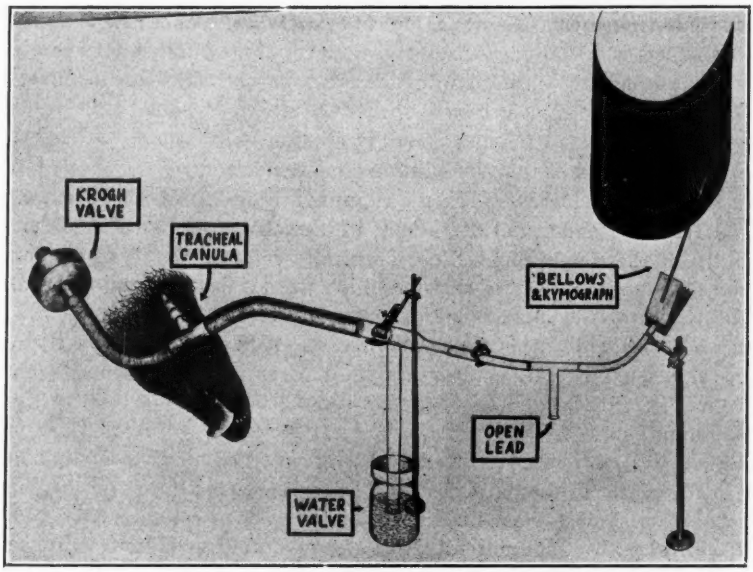

Fig. 1.

unilateral phrenicectomy, but should afford some insight into the conditions prevailing during the period immediately following upper abdominal operations.

METHOD

Dogs were subjected to bilateral thoracotomy* under positive pressure anesthesia, and a silver wire was looped around each phrenic nerve just above its entrance into the diaphragm. The wound was closed with due care to inflate the lungs fully before closure. The ends of each wire loop were buried in the subcutaneous tissues so as to allow easy identification at a later date. One or more days after recovery from the operation the animal was given nembutal intraperitoneally. A T-shaped

*Thoracotomy is necessary to assure inclusion of all the fibers of the phrenic nerve. Surgical exposure of the phrenic nerve in the dog's neck would be preferable, but the identification of all its branches is very difficult.

cannula was placed in the trachea. To one end a Krogh inspiratory valve was attached and to the other an expiratory water valve (Fig. 1). Connected to the latter was a tube of much smaller caliber which led to a Brodie bellows with a lever recording on a smoked drum. A vent was provided for the air in the bellows to permit collapse of the bellows at the close of each expiratory blast. This arrangement permitted an easy exit for the expired air, a small fixed portion of which was delivered to the bellows. The height of elevation of the lever measured in millimeters on the kymograph was taken as a gauge of the force of the expiratory blast.

Cough was produced by stimulating the larynx with Dakin's solution or by mechanical irritation. Powerful expirations usually resulted which were equivalent to a vigorous coughing spell that might occur spontaneously in an intact animal. We could not always elicit maximal expirations by this method. Prolonged traction on the tongue or severe stimulation produced by a strong pull on the mesentery of the small intestine* produced expiratory efforts which almost invariably gave as high an elevation of the writing lever as the coughs due to laryngeal irritation. Repeated stimulation by these methods soon gave satisfactory uniform responses on the smoked drum except that the first few responses were as a rule higher than the later ones. Once a series of uniform responses was recorded, the silver wire loops were extracted from the chest, thus avulsing the phrenic nerves without allowing pneumothorax to occur. The stimuli were then repeated and the responses recorded.

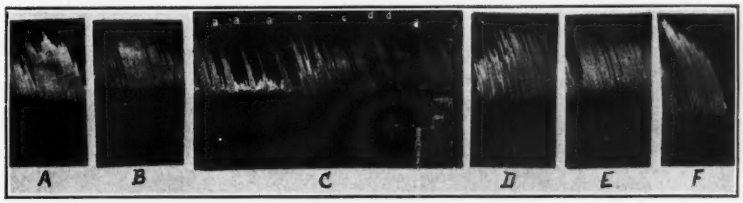

Fig. 2.—Experiment I. *A*, The respiratory response to irritation of larynx before bilateral phrenic exeresis. Maximum expiratory blast 33 mm.

B, Same as *A*, after bilateral phrenicectomy. Maximum expiratory blast 29 mm.

C, *a* represents a series of spontaneous intermittent coughing spells preceding bilateral phrenic exeresis. Maximum expiratory blast at the three points marked *a* was 28 mm., 28 mm., and 27 mm. Left nerve avulsed at *b*, right at *c*; *d* represents the same response continuing after both nerves have been avulsed. Maximum expiratory blast at *d* was 28 mm., 27 mm., and 26 mm.

D, The respiratory response to strong traction on the mesentery of the small intestine before bilateral phrenic exeresis. Maximum expiratory blast 36 mm.

E, Same as *D*, after bilateral phrenic exeresis. Maximum expiratory blast 34 mm.

F, None of the responses preceding phrenic avulsion illustrated in sections *A*, *C* and *D* equalled those obtained when the experiment first began. One of the latter is shown in *F*. (Response to tongue traction 45 mm.) However, none of the measurements comparing the expiratory force before and after avulsion of the phrenic nerves was made until the responses before avulsion had reached a fairly uniform level.

RESULTS

Four experiments were done in this way. Since the observations proved to be reasonably uniform in all four, the details of one experiment (Experiment I, Fig. 2) will suffice for a general description. Bilateral thoracotomy was performed on a healthy young adult dog (weight 18 kg.), and silver wires were looped around each phrenic nerve and the chest was closed. Four days later the dog was given

*The abdominal incision required for this purpose does not affect the force of the cough. Fig. 5 shows the force of the cough before (*A*) and after (*B*) a long abdominal incision.

13 c.c. of a 6 per cent solution of nembutal intraperitoneally, and a tracheal cannula was inserted and connected to the apparatus as described. Traction on the tongue (*F*, Fig. 2) caused a sustained series of forced expirations which reached a maximum of 45 mm. After a short period other stimuli such as traction on the mesentery of the small intestine or scratching the larynx with a sharp instrument produced expiratory blasts of decreasing force* until maxima ranging between 36 mm. and 33 mm. respectively were reached and maintained on repeated trial (*D* and *A*, Fig. 2). These responses were taken for comparison with those following avulsion of the phrenic nerves. In *C*, Fig. 2, at points marked *a* the dog was having coughing spasms which were apparently spontaneous. During this period both phrenic nerves were avulsed, the left at *b*, the right at *c*. This produced severe stimulation and a marked increase in respiratory activity analogous to what was observed when traction was applied to the tongue or the

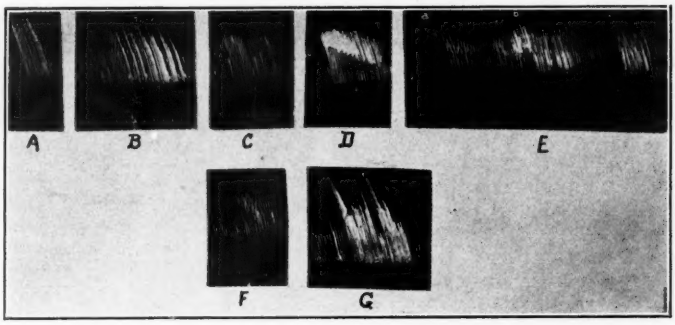

Fig. 3.—Experiment II. *A*, The respiratory response to irritation of the larynx before bilateral phrenic exeresis. Maximum expiratory blast 30 mm.

B, The same response as in *A* after phrenic exeresis. Maximum expiratory blast 30 mm.

C, The respiratory response to strong traction on the tongue before bilateral phrenic exeresis. Maximum expiratory blast 25 mm.

D, The same response as *C*, after phrenic exeresis. Maximum expiratory blast 27 mm.

E, The response to pain at *a* (left phrenic nerve avulsed), at *b* (right phrenic nerve avulsed), and at *c*. Maximum expiratory blast at each of these three points was 28 mm., 30 mm. and 30 mm. respectively.

F, The response to strong traction on the mesentery of the small intestine after bilateral phrenic exeresis. Maximum expiratory blast 28 mm.

G, None of the responses preceding phrenic avulsion illustrated in *A* and *C* equals those at the beginning of the experiment, one of which is illustrated in *G* (maximum expiratory blast following laryngeal irritation 45 mm.). But none of the measurements comparing the expiratory force before and after avulsion of the phrenic nerves was made until the responses before avulsion had reached a fairly uniform level.

intestinal mesentery. The "spontaneous" coughs (points *d* in *C*) continued after the exeresis of the nerves with the same force as before,

*One might expect increasing exhaustion of the animal to contribute to the progressive decline in the force of the expiratory blast. The continued freshness of response of the respiratory apparatus to repeated stimuli after adequate intervening periods of rest argues against this. The animal exhaled against the resistance of a water valve, but this was extremely slight since the rubber tube to the water jar projected only just beneath the surface of the water.

points *a* measuring 28 mm., 28 mm. and 27 mm., points *d* measuring 28 mm., 27 mm. and 26 mm. Laryngeal irritation gave a response of 29 mm. as contrasted with a level of 33 mm. before phrenic exeresis (*B*). Traction on the mesentery gave a maximum of 34 mm. as against a 36 mm. level before phrenic exeresis. The dog was killed shortly after these observations. Autopsy was negative except that both phrenic nerves were torn and slight patchy atelectasis was present in both lungs, a finding common to all the dogs studied. (That the atelectasis was probably related to the preliminary thoracotomy is suggested by our failure to find atelectasis in two dogs subjected to the same experiment but in which thoracotomy and phrenic avulsion were not done.)

The experiment suggests that there is no essential difference in the force of a maximal expiratory blast before and after phrenicectomy.

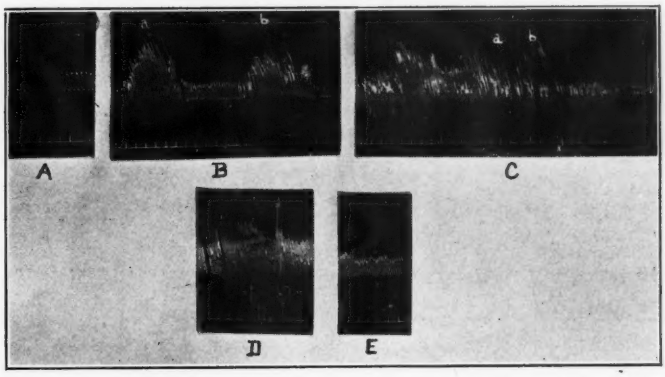

Fig. 4.—Experiment III. *A*, Normal respiratory excursions, expiratory blast 8 mm.

B, *a* shows the maximum respiratory response to pain (strong traction on mesentery of small intestine). Maximum expiratory force 31 mm.; *b* same, with a maximum expiratory force of 25 mm.

C represents a continuous series of coughs which appeared without any special stimulation. At points *a* and *b* the phrenic nerves were avulsed. Whether the force of the expirations declined from a maximum of 30 mm. before avulsion to 25 mm. afterward spontaneously or because of the avulsion cannot be stated. The cough seemed to be accompanied by maximum effort at all times, and was so violent that a loop of eviscerated gut was thrown into the air with each expiration.

D shows the response to laryngeal irritation after avulsion of the nerves. Force of maximum expiratory blast 25 mm.

E, Quiet breathing after avulsion of nerves. Maximum expiratory blast 7-8 mm.

Such a conclusion is justifiable only if the measurements used for comparison can be considered maximum expiratory efforts. An apparent objection appears in the observation that the maximum reading early in the experiment was 45 mm. as compared with later readings of 33 mm. to 36 mm. This would indicate either that the latter were not maximal responses to the stimuli or that the stimuli themselves were not applied with uniform intensity. If the responses were not maximal, we might expect variations in both directions rather than

a progressive decline in the reading to a level which remained reasonably uniform. The stimuli were of a crude type applied as uniformly as possible, but of course they were hard to standardize quantitatively. Since a stable degree of expiratory force was shortly reached on repeated stimulation, it is fair to assume not only that the stimuli were of about equal intensity, but also that the responses used for comparison before and after phrenicectomy represented a maximal effort at the time they were measured.

An examination of the records of Experiments II and III (Figs. 3 and 4) shows findings substantially the same as those in Experiment I. In Experiments I and III it will be noted that in some instances the expiratory force after avulsion of the nerves is smaller by a few millimeters than before. This difference though slight is not wholly negligible. The explanation may lie in the possible circumstance that the volume of air available for cough is lessened by the nerve injury

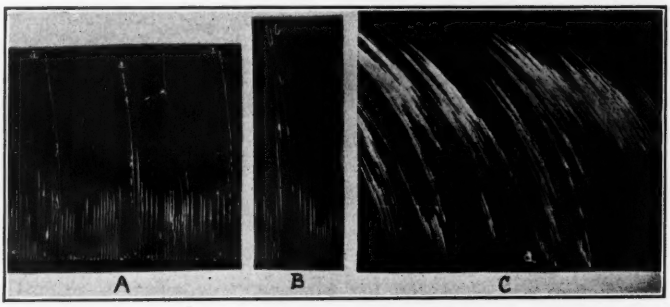

Fig 5.—Experiment V. *A*, *a* represents a cough in response to irritation of the larynx.
B, *b* shows the same after opening the abdomen widely by a longitudinal incision.
C, A series of coughs unaltered in force as a result of opening the upper abdomen by a long incision at *a*.

and that bilateral phrenicectomy thus operates in a very mild way to decrease the force of the cough. It is nevertheless clear that bilateral phrenicectomy does not, at least immediately, produce a substantial difference in the power of a forced expiration. If the difference is of consequence after a longer period, as the observations of Carlson and his coworkers[1] suggest, it cannot be ascribed to any changes intrinsic in the diaphragm as a muscular septum.

It is generally assumed that following laparotomy cough is restricted on account of the limited capacity of the abdominal muscles to exert pressure on the peritoneal cavity. It is also possible that the gaseous distention of the gastrointestinal tract, commonly present, acts as a compressible air cushion which serves to nullify some of the contracting effort of the abdominal muscles during the act of coughing. A snug abdominal binder, by taking up the slack to some extent, might

thus be regarded as advantageous so long as it does not simultaneously restrict the mobility of the costal margins. Whether or not a surgical binder actually makes the effort to cough more efficient is uncertain because at the same time that it assists the abdominal muscles by restricting the extent of their excursion, it also presumably pushes the diaphragm higher and so decreases the volume of the expiratory blast. Since the position of the normally innervated diaphragm may be of importance in relation to the effectiveness of cough, an observation was made as follows:

A healthy adult dog was subjected to light anesthesia with nembutal and connected to the apparatus shown in Fig. 1. Coughing spasms

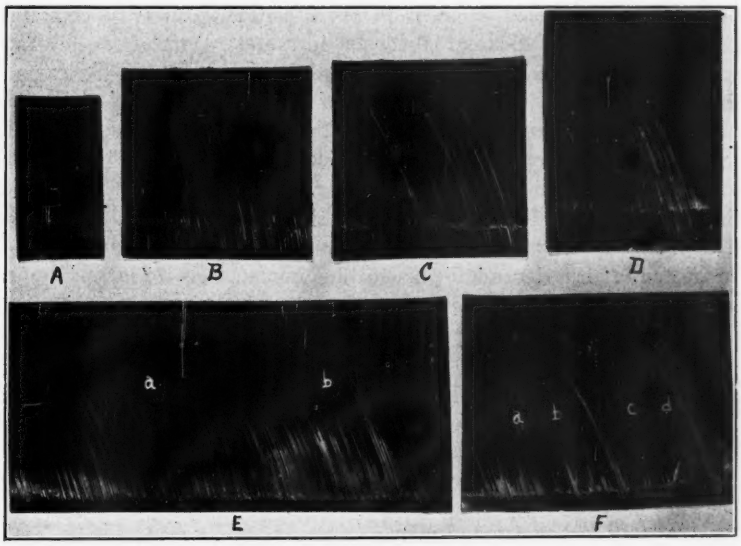

Fig. 6.—Experiment VI. *A*, Normal quiet breathing.

B, Cough in response to stimulation of larynx and cough.

C, Cough in response to stimulation of the larynx—lower abdomen compressed by a tight strapping.

D, Cough in response to stimulation of the larynx—entire abdomen exclusive of costal margins very tightly strapped.

E, The same as *E* until at *a* the costal margins were immobilized by adhesive strapping, which was removed at *b*.

F, Cough response with abdomen, costal margins and chest compressed. At *b* the chest and costal margin compression was released—at *c* it was reapplied, and at *d* it was again removed.

were elicited by laryngeal irritations (*B* in Fig. 6), and when a uniform maximum level on the smoked record was reached (*B*), the lower abdomen was tightly compressed. This did not decrease the force of the cough (*C*). Nor did very tight strapping of the entire abdomen, exclusive of the costal margins, alter this result (*D*). Only after restricting the excursion of the latter did the cough become less forceful

(*F*). Release of compression of the chest and costal margins restored the force of the cough to its previous level. In the dog, pressure applied to the abdomen may merely spread the costal margins without elevating the diaphragm, but the excursion of the latter should nevertheless be considerably reduced. The power of the cough is, however, unaffected.

SUMMARY

In view of the conflicting opinions as to whether paralysis of the diaphragm facilitates or hinders cough, the question was subjected to experimental study by direct measurement in the dog of the force of a series of maximal expiratory blasts before and after bilateral phrenic exeresis. Paralysis of the whole rather than half the diaphragm was produced in order to avoid confusion in evaluating the data because of paradoxical movement in unilateral paralysis. In this way we obtained data showing that the diaphragm, regarded merely as a paralyzed muscular septum transmitting the force of the intra-abdominal pressure, does not facilitate cough. Occasionally slight decrease in the force of the cough occurred, which we attributed to other factors. Some evidence is also presented to indicate that limiting the excursion of the diaphragm by tight abdominal strapping does not impair the effectiveness of cough until the costal margins are also restricted, a situation analogous to that immediately following upper abdominal operations.

CONCLUSIONS

These experiments therefore offer evidence that when, as is the case after upper abdominal operations, the entire diaphragm is nearly in the full expiratory position, it affords neither help nor hindrance to the force of the expiratory blast. The same is, on the whole, true in the case of a totally paralyzed diaphragm. If the cough is somewhat less efficient, it must be related to other factors such as diminished expansion of the lungs with consequent decrease in the air available for the expiratory blast.

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SECONDARY ASPERGILLOSIS (ASPERGILLUS NIGER) SUPERIMPOSED UPON BRONCHIECTASIS

Report of a Case

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SINCE its discovery in 1842 by Bennett, medical literature contains frequent reports of pulmonary aspergillosis. E. F. Wahl and M. J. Erickson collected 54 cases chiefly from foreign literature, 11 of which were probably primary and 43 secondary. Finding, however, the causative organism to be *Aspergillus niger* instead of the usual *Aspergillus fumigatus* is decidedly unusual if not worthy of the term "rare." Wheaton, who found it in 1890, accompanying tuberculosis, is probably the first to report it. Since then Renon, Sayers, and Hansen have added to the literature. It is because of this infrequency that the following case is offered.

REPORT OF A CASE

A colored male, aged fifteen years, was admitted to Waverly Hills Sanatorium, January 16, 1934. His family history was essentially negative, as was his personal history, save that of the respiratory system. In 1926 and again in 1927 the patient had had pneumonia. In 1928 a tonsillectomy had been performed. In 1929 the patient had pneumonia again, following which he developed a left-sided empyema. On Jan. 1, 1930, a rib was resected and open drainage instituted for thirty days at a Louisville hospital. In the summer of 1932 he developed a productive cough which was accompanied by pain in the left chest. The sputum at that time was "a thick yellow phlegm." In February, 1933, he was examined at a city dispensary and pronounced free from tuberculosis. His symptoms remained, however, so he returned to the dispensary in November, 1933, and was then told that he had tuberculosis and was sent home to bed. The patient about this time noticed that the sputum was frequently gray and speckled with small black particles. In December, 1933, he had night sweats every night for a week and in January, 1934, just before admission to Waverly Hills Sanatorium, he experienced one chill. On admission to the Sanatorium his appearance was fairly good. He complained of a productive cough, occasional pain in the left chest, and frequent indigestion. The coughing would become worse when the patient lay down and interfered with his sleep. Upon awaking each morning he found his pillow wet with sputum. He expectorated 10 to 12 ounces daily, which was not fetid. This was at times gray, at others yellow. The temperature was frequently up to 99° at 5 P.M. and on several occasions 99.4°. The pulse range was 80 to 100. His weight was 115 pounds, height 5 ft. 8 in.

On physical examination his heart was found normal, abdomen negative, and liver within normal limits. Lymph nodes were not palpable. Chest examination showed the scar at site of former rib resection with an absence of regrowth of the rib

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Received for publication, October 4, 1934.

resected, the rib ends being palpable. There was slight retraction and diminished expansion of the left chest. The right chest was negative. On the left the percussion note was impaired throughout. Breath sounds, whispered voice, and vocal fremitus were decreased throughout except at the lower angle of the scapula where whispered voice sounds were slightly increased. Both moderately coarse and coarse râles were heard after coughing from the fifth vertebral spine to the eighth vertebral spine; the angle of the scapula being the site where they were most numerous. A roentgenogram of the chest showed: right side, root moderately heavy, the parenchyma appeared relatively clear; left side, root moderately heavy. There was a moderate amount of infiltration and fibrosis scattered through the lower half.

A lipiodol injection was made of the lower left lobe; and the bronchi, particularly behind the heart shadow, showed marked cylindrical dilatation and some sacculation. Further lipiodol injections were made of all the remaining lobes, including the bronchus to the lingual tip of the upper left lobe. All were negative except the lower right lobe, which showed a slight dilatation of the bronchi with sacculi in chain formation, giving each bronchus a beaded appearance. Roentgenograms of the paranasal sinuses were negative. The Kahn test was negative. The red cell sedimentation test was within normal limits with a one-hour reading of 10 mm.; 2 hours, 37 mm.; 6 hours, 53 mm.; 12 hours, 60 mm.; 24 hours, 75 mm. Sputum examinations were made. A series of 7 concentrations was negative for tubercle bacilli. Checked examinations were made for spirochetes, anaerobic organisms, and fungi. Occasional spirochetes were found but no anaerobes. The culture for fungi was positive for *Aspergillus niger*, identified by Thelma I. McFall of our own laboratory staff and confirmed by Helen C. Jeffries of the Kentucky State Board of Health. The sputum specimens were obtained after the mouth was rendered as sterile as possible. To avoid complications a bronchoscopic examination was deferred until the *Aspergillus niger* was thought to be destroyed by iodide therapy. Potassium iodide was given by increasing dosage method until iodide eruption appeared. After subsidence of the eruption, treatment was repeated. On April 26, 1934, bronchoscopy was performed. The right side was examined first. The membrane appeared only slightly reddened. The small carinas were sharp and smooth, and there was no stenosis of the bronchial openings. There was somewhat more reddening of the lowermost portion of the bronchial tree but no stenosis. No free pus occupied the bronchus, but around each opening of a bronchus was a fine yellow ring. There was much more reddening on the left. The left upper lobe bronchus was not seen, but the lower lobe tree was bright red, edematous, and swollen so that most of the bronchial orifices were partially closed. One lowermost orifice appeared almost completely closed. No pus was seen, but about 3 c.c. of bloody material was aspirated for smears and cultures. Examination of the material showed *Streptococcus hemolyticus* the predominating organism. Also present were *B. influenzae, B. melaninogenicum* and *M. catarrhalis.*

Additional history from the patient reveals only one contact with grain. He had several pet pigeons which he fed regularly with grain purchased from a nearby feed store. After iodide therapy the sputum was still negative for tubercle bacilli. On May 14 one sputum culture showed a growth of Penicillium which was assumed to be a contamination, as it was never again obtained. Following the lipiodol injections there was a marked reduction in the amount of sputum and a corresponding reduction in cough. By March the daily sputum totaled less than an ounce. After iodide therapy the sputum became very scant, the cough was practically absent, and the patient no longer drooled on his pillow. Because of marked improvement the patient decided to go home and was discharged on June 7, 1934. A sputum culture on that date showed *Aspergillus niger* still present.

DISCUSSION

Because of repeated cultures of *Aspergillus niger* over a five-month period it is thought that the fungus definitely had the lung as its source. From the bronchoscopic examination it appears as though the yellow sputum came from the right lung. By process of elimination the gray which was positive for *A. niger,* evidently came from the left. The 3 c.c. of bloody fluid aspirated for culture during bronchoscopy was probably fluid resulting from trauma to edematous tissue. That, together with the fact that the lung was thoroughly drained previously, accounts for the negative culture for *A. niger.* Bronchoscopy was performed with the idea of possible lobectomy, and direct culture was purely incidental. This case supports some experimental work with *A. niger* by N. Bethune and W. Moffatt in that (1) the *A. niger* was implanted on a chronic inflammatory base, which they thought necessary for its growth as a parasite, and (2) there was no extensive fibrosis and relatively slight lesions were produced.

I wish to express my appreciation of the interest and assistance of Drs. Benjamin L. Brock, Lincoln Fisher, and Orville Ballard. I am deeply indebted to Dr. Clarence Bird of the Louisville City Hospital Staff who performed the bronchoscopy.

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METHODS OF PRODUCING EXPERIMENTAL PLEURAL CONGLUTINATION*

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IN THE course of an investigation of the effect on the heart of chronic diseases of the thorax and respiratory organs we found ourselves in need of a reliable method of producing widespread pleural conglutination. In our efforts to find such a method we sacrificed a dozen dogs before we discovered that many procedures which seemed promising on a priori grounds were either lethal or ineffectual. Eight dogs died of necrosis of the pleura and massive pleural effusion as a result of the introduction of iodoform; in 3 of these animals a thick aqueous suspension was used, in 2 the dry powder, and in 3 iodoform gauze. One dog survived the insertion of fine sand, but the sand became embedded in the parietal pleura and no pleural adhesion occurred. Scarification of the pleura with emery paper (3 dogs), and with a wire brush (3 dogs), led in each group to 2 deaths from pleural necrosis and effusion; the remaining animal in each group was found to have pleural thickening without adhesion.

A search of the literature disclosed the fact that our discouraging experience merely reduplicated that of others. A veritable multitude of experimental procedures designed to cause adhesion between the two layers of the pleura, usually for surgical purposes, has been proposed. These procedures include: (1) the intrapleural injection of chemical or bacterial irritants, such as zinc chloride paste, solutions of silver nitrate, tincture of iodine and Lugol's solution, aleuronate, formalin, phenol, peptone, ether, alcohol, and tubercle bacilli and staphylococci; (2) methods combining chemical and mechanical irritation, such as inserting tampons of gauze soaked in zinc chloride solution, iodoform, or iodine, common sponges soaked in dilute hydrochloric acid, and sewing the pleurae together with sutures saturated with oil of turpentine or juniper; (3) purely mechanical or traumatic means, including the insertion against the outer surface of the costal pleura or between the pleurae of masses of paraffin, silk pads, rubber sponges, plain gauze tampons, plain cloth tape, lycopodium spores, and Laminaria, injury by crushing, curettage, scarification, and electrolysis, and immobilization by thoracoplasty; (4) irradiation with solar or roentgen rays; and (5) by diathermy, and

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Received for publication, January 5, 1935.

by ligating the internal mammary and superior epigastric arteries. A few of the more important contributions are listed at the end of this paper.

The insertion of plain gauze or cloth tape between the two layers of the pleura is probably the method most worthy of serious consideration, especially if the desideratum is simple adhesion over a comparatively large area without simultaneous compression of the lung. The encouraging experience of Bettman, in whose hands this method proved to be uniformly safe and successful, was one of our reasons for adopting it. After a number of preliminary experiments we developed an operative technic which differed somewhat from Bettman's. The lower incision (in the tenth or eleventh intercostal space) was carried into the pleural cavity, but the upper incision (in the second or third intercostal space) penetrated the skin and superficial fascia only. A curved needle, threaded with a catgut suture considerably longer than the distance between the two incisions, was thrust, eyelet foremost, through the intercostal muscle and parietal pleura underlying the upper incision, caught in the fingers of the hand which had been inserted through the lower incision, and withdrawn through the lower incision. This end of the suture was affixed to a strip of plain cloth tape, the needle removed, and the tape drawn upward between the two layers of the pleura by traction on the free end of the suture, which had been left outside the upper incision. The upper end of the tape was then anchored by passing the attached suture back and forth through the intercostal muscle underneath the upper incision. By this means 5 strips of tape were so placed that they lay fanwise between the upper and lower incisions and equidistant from each other across the hemithorax. Near their lower ends they were sutured to the pleural surface of the intercostal muscle which had been divided by the lower incision, or to that of the intercostal muscle next above it, and their ends tucked into the phrenicocostal sinus. The incision was approximated by drawing its adjacent rib margins together with heavy stay sutures of chromic catgut. Care was taken to be sure that the tape ends were buried in the pleural sac before suturing the fascia and skin. The diaphragmatic pleura could be similarly treated through the same lower intercostal incision by depressing the diaphragm with malleable retractors and suturing strips of tape or a single large layer of gauze to its musculature. Subcutaneous emphysema due to leakage from the residual pneumothorax was avoided in all but a few animals by closing the lower incision as tightly as possible. It was necessary to observe the strictest aseptic and antiseptic precautions throughout, to limit the anterior extent of both incisions as much as possible in order to prevent them from becoming grossly contaminated when the animal lay on its belly, and to preserve an adequate blood supply about the incisions; but not even the most meticulous attention to these

and other technical details enabled us to escape a postoperative mortality of about 20 per cent from empyema or wound infection.

In every instance the tapes were left in place permanently. The ultimate result of this procedure was that they became embedded in a growth of dense fibrous tissue which produced indivisible conglutination of the contiguous visceral and costal pleurae. In several animals, however, the desired end was not fully achieved, not for lack of adhesion, but because some of the tapes escaped from their attachments and collected in a mass which was too small to be effective.

CONCLUSION

The insertion of plain gauze or cloth tape between the visceral and parietal pleurae is probably the best experimental method of producing widespread pleural conglutination without simultaneous compression of the lung.

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INVOLVEMENT OF THE SYMPATHETIC NERVES AS A COMPLICATION OF ACUTE EMPYEMA

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J. W. T., a white male, thirty-three years of age, first consulted Dr. J. W. McGee on May 28, 1934, with the complaints of weakness, pain in the left chest and shoulder, and shortness of breath—all of one week's duration.

The patient stated that he had felt perfectly well until one week previously, when he noticed the gradual onset of the above symptoms which became progressively more severe and were accompanied by chills and fever. The past history was negative except that he had had an appendectomy many years ago, and for the past three or four years he had been a heavy drinker. Physical examination revealed dullness, diminished fremitus, and diminished breath sounds over most of the left chest. The heart sounds were indistinct, and the liver was enlarged two fingerbreadths below the right costal margin. Examination of the urine was negative. X-ray examination of the chest confirmed the presence of a large amount of fluid in the left pleural space and the heart was displaced to the right. A needle was inserted in the left pleural cavity below the angle of the scapula; and seropurulent fluid, having an odor suggestive of that produced by the colon bacillus, was withdrawn. Thoracentesis was repeated several times; and on May 31, 1934, when the pus had become thick, I resected a portion of the eighth rib and instituted closed drainage. At the operation a subcutaneous abscess containing about 200 cubic centimeters of thick pus was found over the lower chest wall which was evidently due to infection of the subcutaneous tissue by the aspirating needle. Stained smears and cultures made from the pus from the pleural cavity revealed mixed gram-positive and gram-negative cocci and bacilli. No tubercle bacilli were found. The patient made an uneventful recovery and was dismissed from the hospital on June 18, 1934, with the tube still in place. On June 20, during a period of hot weather, it was noticed that, although there were beads of sweat standing out on his face and body and right arm, the left hand, arm, axilla and the shoulder over the acromial process were perfectly dry. On palpation a marked difference could be noticed in the surface temperatures of the two arms: the left arm, hand, and shoulder were much warmer than the right. An x-ray picture of the spinal column at this time revealed no pathologic condition. The left arm remained dry and hot for a period of one month, and then gradually returned to normal; and during this time the patient felt well and continued to make very satisfactory progress.

It is evident that this patient had some lesion which cut off the sympathetic nerve supply of the upper extremity, and this, as a complication of empyema, is unique in my experience—nor have I been able to find any reference to such a condition in the medical literature. The sympathetic nerve supply of the upper extremity is derived from the thoracic segments, probably those from the fourth to the ninth. Preganglionic fibers from those segments ascend in the thoracic trunk to the middle and inferior cervical, and first and second thoracic ganglia. From these ganglia fibers pass to the brachial plexus and are distributed to the upper extremity along with the branches of the plexus. Since the thoracic trunk lies along the spinal column in rather close proximity to the parietal pleura, it seems probable that inflammation involving the pleura might extend to and involve the thoracic trunk, and I believe that in this case such an involvement occurred.

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Received for publication, November 22, 1934.

Department of Reviews and Abstracts

CONDUCTED BY DUFF S. ALLEN, M.D., ASSOCIATE EDITOR

Selected Abstracts

Rist, F.: La Collapsothérapie de la bronchiectasie. (Collapsotherapy in Bronchiectasis.) Bull. Acad. de méd. **108:** 1451, 1932.

Rist believes in the efficacy of collapsotherapy in the cure of bronchiectasis. In favor of his opinion he reports his personal experience with 59 cases of bronchiectasis. In 22 of his cases pneumothorax could not be induced because of a complete pleural symphysis. It is to be noted that in none of these cases were there clinical or radiologic signs indicating that such pleural symphysis was present. Of the remaining 37 patients treated by pneumothorax, 20 have been cured by the induced collapse of the lung. Seventeen patients were not improved or were made worse. In this group are those in whom collapse of the lung was unsuccessful by pneumothorax and those in whom the pneumothorax angulated the "bronchus of drainage" and thus brought a train of pneumonic accidents. In the group of 20 cured patients are 7 who still carry a chronic pneumothorax and 13 in whom the lung has been allowed to reexpand without occasioning any relapse.

In these patients the bronchiectasis has not disappeared as is revealed by lipiodol bronchography, but the superadded infections phenomena, the immediate cause of the symptomatology, have been eliminated by the collapsotherapy. Rist adds that if pneumothorax is impossible, phrenicectomy may be employed as a supplementary measure of collapsotherapy.

Maurice Berck.

Hutinel, J., Kourilsky, R., and Nicholas, E.: Les Abcès du Poumon chez l'enfant. (Abscess of the Lung in Children.) Arch. de méd. d. enf. **35:** 697, 1932.

Abscess of the lung is relatively uncommon in infants. Contrary to what is observed in adults, however, monomicrobic nonfetid lung abscess is more common in infants than is acute putrid abscess. Abscess of the lung in infancy is usually primary, but may be a sequel to an acute pneumonic episode. A considerable number of abscesses follow tonsillectomy and intrabronchial foreign body.

Pleural complications are very frequent, are of great significance, and demand great clinical attention. The authors describe and classify the following types of lung abscess in infancy:

1. Those due to the pneumococcus.
2. Those due to the staphylococcus.
3. Those due to the enterococcus.
4. Amebic abscess.
5. Acute putrid abscess.

The authors describe the evolution of a lung abscess in three stages, schematically:

1. The stage of acute pneumopathy.

2. The stage of evacuation through a bronchus and the formation and revelation of a cavity.

3. The stage of prolonged bronchial drainage.

For simple acute abscess in infancy spontaneous cure, to the authors, seems to be the general rule.

Considerable attention is drawn to the difficulties of diagnosis in the very young who do not expectorate, but swallow the purulent bronchial secretion. It is often necessary to inspect the vomitus to obtain a clue as to the diagnosis. The essential point in the diagnosis is the appearance during the course of an acute or subacute pneumonopathy of purulent bronchial secretion plus the radiographic image of a pulmonary cavity with a fluid level.

The more common monomicrobic nonfetid lung abscess in infancy frequently underwent spontaneous resolution within two months. The usual supportive measures and vaccine therapy were employed. Bronchoscopic aspiration is but rarely used in France. Collapsotherapy is rejected. When improvement does not take place, pneumonotomy in two stages is performed. If the abscess is complicated by empyema, thoracotomy and drainage are done with a minimal pleural opening.

Maurice Berck.

Barrett, N. R.: Diverticulum of the Thoracic Esophagus. Lancet **224**: 1009, 1933.

Diverticula of the thoracic esophagus are much less frequent than those of the cervical esophagus. Barrett has found only 115 cases in the literature, but notes that the frequency of their observation is increasing as knowledge of the condition becomes more widespread. Their symptomatology may be entirely silent or may be exceedingly misleading because of the presence of both pulmonic and gastrointestinal manifestations due to compression of the vagus or splanchnic sympathetic nerves. The roentgenogram, in practically all the cases, makes the diagnosis.

The author reviews the different surgical technics that have been employed and terminates with the following personal observation upon an operatively cured case.

A woman of fifty-nine years had noted for the past two years a sensation of severe thoracic compression at the beginning of each meal. This continued for several minutes, and only after this time was she able to finish her meal normally. She never vomited. No weight had been lost and her general condition was excellent. A roentgenogram showed a thoracic esophageal diverticulum on the right side.

The following procedures were done. For two consecutive days, pneumothorax was induced on the right side (fillings of 450 c.c. and 500 c.c.). On the third day Barrett operated under intratracheal ether anesthesia. A bougie was introduced per os into the diverticulum; an anterior incision was made in the right sixth intercostal space and extended from the axillary line to the sternal margin. The pleura was cautiously opened, after a preliminary small incision through it, and thorough exposure revealed the diverticulum, covered by parietal pleura which was then incised. Many peridiverticular inflammatory adhesions were separated, and the diverticulum was carefully freed. The pedicle of the diverticulum lay parallel to the esophagus and was 5 cm. long. The pedicle was crushed and then severed with the diathermy knife. The esophageal hiatus at the root of the pedicle was then closed with two tiers of sutures and reinforced by a pleural plastic.

Feeding was maintained by gavage (nasal tube) for nine days. No nutrition was given by mouth during this time. Atropinization decreased the salivary secretion. The postoperative course was smooth apart from a small pleural effusion at the right base which spontaneously absorbed.

Seen six months later the patient was cured. The roentgenogram of the esophagus was then normal.

Maurice Berck.

Mishulow, Lucy, Melman, Mildred, and Romano Marie: An Improved Method of Direct Smear Examination for Acid-Fast Bacilli in Sputums. Science **80:** 143, 1934.

This report is from the Bureau of Laboratories, New York City Department of Health. The chief question under discussion is whether or not the time-consuming method of concentrating sputum before examining it for tubercle bacilli gives more positive results then the ordinary direct smear examination. *It was found that in no instance was a positive result obtained after concentration when it was found negative on the direct smear.*

The method of "direct smear examination" employed was as follows: "The sputum was poured into a petri dish and was examined for mucous flakes. If the sputum was fluid, the flakes were collected by means of a pipette and were expelled on two chemically clean, new

slides making fairly thick smears. If the sputum was very mucoid, a heavy wire loop was used instead of a pipette. The smears were allowed to dry in the air and were then stained by a slightly modified Ziehl-Neelsen method, in which the counterstain was 1:1 000 dilution of brilliant green instead of methylene blue. Both smears were thoroughly examined for acid-fast bacilli with the aid of a mechanical stage." The method followed in the concentration of the sputum is also described.

Harry C. Ballon.

Landon, John Fitch: An Analysis of 88 Cases of Poliomyelitis Treated in the Drinker Respirator, With a Control Series of 68 Cases. J. Pediatrics **5**: 1, 1934.

The author's findings offer considerable food for thought. Although experiences differ, nevertheless, it will become obvious from the conclusions which follow that similarly well-controlled observations are certainly in order.

"1. Eighty-eight cases of poliomyelitis with respiratory distress, treated in the Drinker respirator, are compared with sixty-eight cases of patients suffering from respiratory embarrassment in which the machine could not be employed because of the scarcity of respirators.

"2. The respirator-treated cases and control cases are analyzed according to the degree of severity and by type of paralysis. No appreciable difference in the mortality of the patients dying in the hospital in the two groups is noted.

"3. Of the cases treated in the respirator and discharged from the hospital able to breathe spontaneously, nearly five times as many were dead at the end of eighteen months as in the comparable control group.

"4. *The combined clinical and pathologic findings strongly suggest that the respirator as employed in 1931 by the communicable disease hospitals may predispose the pulmonary apparatus to subsequent infection or collapse.*"

Harry C. Ballon.

Sanes, S., and Kenny, F. E.: Huge Tension Cavity in Primary Pulmonary Tuberculosis in an Infant. J. Pediatrics **5**: 51, 1934.

The authors report a case of primary pulmonary tuberculosis with cavitation in a ten-month-old negro infant. The primary cavity in this case was of extremely large size and of the tension type. The literature on cavernous pulmonary tuberculosis in infancy is summarized. The case under discussion is of particular interest because it draws attention to the tremendous size which a tuberculous cavity in an infant may attain. Cystic degeneration of the lung, pneumothorax, and intrathoracic hernia would obviously have to be considered in the different diagnosis.

Harry C. Ballon.

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Eighteenth Annual Meeting

New York, June 3, 4 and 5, 1935
Hotel Headquarters—Waldorf-Astoria

Program

The length of the program requires that the presentation of each address (except that of Mr. Davies and of Mr. Roberts) be strictly limited to 15 minutes, and the discussion of it to 10 minutes. The discussion of related subjects will be deferred until after the last of these has been presented. It is expected that the papers will be delivered to the secretary or to the editor immediately after their presentation.

Monday, June 3

9:00 a.m.

Business Meeting.

9:30 a.m.

1. Report of a Case of Esophago-Gastrostomy for Carcinoma of the Esophagus.
   Dr. Harry R. Decker, Pittsburgh.

2. Treatment of Carcinoma of the Esophagus by Combined X-ray and Radium. Reporting a Cured Case of the Upper Third. Instrument Used in Accurately Measuring Involved Area. Flexible Capsule for Accurately Placing Radium.
   Dr. Armistead Crump, New York.
   Dr. Haig H. Kasabach (by invitation).
3. Recurrence of Bronchiectasis Following Mass Ligation of the Hilus of a Lobe. Report of a Case With Comment on Certain Technical Points Pertaining to Lobectomy.
   Dr. H. L. Beye, Iowa City.
4. The Use of the Pedicled Muscle Flap in the Closure of Chronic Bronchial Fistulae.
   Dr. Owen H. Wangensteen, Minneapolis.
5. Pneumonectomy for Carcinoma and Pulmonary Suppuration: Experience in Seven Cases.
   Dr. Richard H. Overholt, Boston.
6. Diagnosis and Treatment of Chronic Empyemata.
   Mr. J. E. H. Roberts, London.

12:30 p.m.

Luncheon.

2:00 p.m.

7. A Critical Study of Our Experiences With Intrapleural Pneumolysis.
   Dr. William A. Hudson, Detroit.
8. The Evaluation of Interpleural Adhesions by Oblique Roentgenography: With Attention to Cautery Pneumonolysis.
   Dr. Cameron Haight, Ann Arbor.
   Dr. Carleton B. Peirce (by invitation).
9. A Roentgen Study of the Mode of Development of Encapsulated Interlobar Effusions.
   Dr. Leo G. Rigler, Minneapolis.
10. Pneumothorax by Open Operation.
    Dr. Franz Torek, New York.
11. Lobectomy in Pulmonary Tuberculosis: Report of a Case.
    Dr. S. O. Freedlander, Cleveland.
12. Surgical Management of Bilateral Cases of Pulmonary Tuberculosis: Report of 100 Cases.
    Dr. Pol. N. Coryllos, New York.
    Dr. G. G. Ornstein (by invitation).

Tuesday, June 4

9:00 a.m.

Business Meeting.

9:30 a.m.

13. Presidential Address.
    Dr. John Alexander.
14. Bronchography Following Thoracoplasty for Tuberculosis.
    Dr. Evarts A. Graham, St. Louis.
    Dr. Henry L. Cabitt (by invitation).
    Dr. J. J. Singer.

15. The Surgical Revision of Unsatisfactory Thoracoplasty by Reoperation and Extraperiosteal (Subscapular) Packing.
    Dr. Thomas J. Kinsella, Oak Terrace, Minn.
16. Resection of Posterior Border of Scapula for Relief of Pain Following Thoracoplasty.
    Dr. Carl R. Steinke, Akron.
    Dr. James T. Villam (by invitation).
17. The Choice of Procedure in Collapse Therapy.
    Dr. E. J. O'Brien, Detroit.
18. General Principles of the Surgical Treatment of Pulmonary Tuberculosis.
    Mr. H. Morriston Davies, Ruthin, North Wales.

12:30 p.m.

Luncheon.

2:00 to 5:00 p.m.

Hospital clinics. The Programs will be announced on June 3

7:00 p.m.

Annual Dinner—Empire Room.

Wednesday, June 5

9:30 a.m.

19. Ewing's Tumor of the Rib: Report of Two Cases.
    Dr. W. P. Herbert, Asheville.
20. Thoracic Complications of Amebiasis.
    Dr. Alton Ochsner, New Orleans.
21. Contributions to the Technique of Pulmonary Embolectomy: An Experimental Study.
    Dr. Gunnar Nystrom, Uppsala, Sweden.
    Dr. Alfred Blalock, Nashville.
22. Infarct of the Lung.
    Dr. I. A. Bigger, Richmond.
23. Artificial Respiration by an Apparatus Which Controls Volume and Pressure. Demonstration on Excised Lung of the Futility and Danger of Certain Methods.
    Dr. William Branower, New York.
24. Observations on the Effect of Hyperventilation on the Postoperative Capacity of Surgical Patients.
    Dr. John H. Powers, Cooperstown, N. Y.
25. Maggot Therapy in Suppurative Lesions of the Lung and Pleura: Case Report and Moving Picture Film (30 minutes).
    Dr. Norman Bethune, Montreal.

12:30 p.m.

Luncheon.

2:00 to 5:00 p.m.

Hospital clinics. The Programs will be announced on June 3.